Holistic Processing of Verbal and Non-Verbal Information in Single Integrated Visual Objects

V. Heidel

A thesis submitted for the degree of PhD

Department of Psychology
University of Essex
Submitted: October 2017

ACKNOWLEDGEMENTS

I would like to first and foremost thank my supervisor, **Dr. Geoff Cole**, for sticking with me throughout my six years and only thinking I had disappeared for good once. Thank you for your patience, feedback and always being prepared to catch back up to where we left off the last time. And a special thank you for saving the day and literally conjuring a red thread out of thin air.
Thank you to **Prof. Chris Barry** for finally agreeing to be my second supervisor and for scaring the Bejesus out of me at just the right time to freak me out enough to get my act together and finish what needed to be finished.
A big thank you also goes to **Dr. Andrew Simpson** for never losing his sense of humour and for believing in me even in the face of overwhelming evidence to the contrary. Thank you for you kind words and support at a difficult time and for always giving me a chance to catch up with myself. And of course, thank you for making my viva a more pleasant experience than I could ever have expected.
Thanks to **Dr. Joanne Ingram** for traveling all the way from Scotland and for actually reading my thesis. I couldn't have asked for a better external examiner and surprisingly quite enjoyed your picking apart of six years' worth of my work.

Thank you to **Dr. Antonia D'Souza** for sharing this special journey with me and for always being a few steps ahead, making me feel that just maybe that final goal was still achievable. You've worked so hard and I have the utmost respect for you.

Last, but never least, I would like to thank my partner, **Dr. Antigonos Sochos**, for supporting me throughout this academic adventure and for putting up with my mood swings, self doubt and procrastination.

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ABSTRACT

The present work examined how holistic, conceptual processing could be achieved by meaningfully integrating verbal and non-verbal information into a single visual object, which would allow simultaneous, complementary encoding of both dimensions. The main interest of the current work was in the exploration of encoding and retention mechanisms associated with holistic processing. While both pictures and words have been investigated in isolation, less research exists to explore the complementary potential of both presentation formats. Even in instances where combined presentation is used, such as the Stroop effect (Stroop, 1935) the primary focus has been on interference rather than facilitation of processing. Overall results showed that holistic integration could be achieved successfully and visual integration of verbal and non-verbal information led to processing of both dimensions as a single object rather than as separate dimensions. While there may not be a direct recall benefit of integrated verbal and non-verbal information, combining pictures and words into a single visual object significantly increases stimulus recognisability regardless of encoding intention. In addition, holistic activation was achieved for verbally ambiguous stimuli. Findings indicate that integrated presentation of verbal and non-verbal information is encoded through a mostly incidental route, which is most accurately tested by using a recognition test. In addition, data show that although participants appear to rely mostly on the verbal dimension for positive identification of targets, non-verbal information is encoded successfully and significantly impacts encoding and retrieval processes. Results suggest that while integrated presentation does not aid free recall, it is highly effective in improving stimulus recognisability.

CHAPTER 1

Introduction

Abstract

The current work aims to offer a novel approach to the investigation and interplay of processing verbal and non-verbal information and their potential for holistic integration. While pictures and words have been extensively researched and their relative merits pitted against one another (Shepard, 1967; Blanc-Brude & Scapin, 2007, Stenberg, Radeborg & Hedman, 1995; Hodes, 1994; Stenberg, 2006), a coherent focus on their complementary potential is sorely lacking from the current literature. While combined use of both dimensions has been employed in studies of learning (Beacham, Elliot, Alty & Al-Sharrah, 2002; Chun & Plass, 1996; Mayer & Anderson, 1991) or text comprehension (Willows, 1978; Hibbing & Rankin-Erickson, 2003), its effect on single item processing and recall has so far been overlooked. Consequently, the present work suggests an investigation into picture and word processing that is aimed at increasing processing efficiency and retention likelihood as a result of complementary use of verbal and non-verbal information in a holistic, integrated design. The present chapter reviews past literature, briefly exploring existing knowledge in the fields of object recognition, Gestalt psychology, language, concepts, mental imagery and picture superiority, as well as various theories of information processing before finishing with the assessment of Stroop and Garner effects – currently the best known paradigm in which verbal and non-verbal information is combined into a single stimulus, although the focus resolutely remains on hindrance rather than facilitation of effective processing. The final section of this chapter, entitled Holistic Processing, reviews how each area is relevant to the current work and how earlier findings relate to the predictions and experiments presented here. The suggested approach for integrated verbal and non-verbal material into a single visual object is described in more detail and a series of examples are provided and discussed.

Object Recognition

A long-standing debate has been going on in an effort to explain how humans construct a three-dimensional mental representation of the world around them from two-dimensional information perceived through the retina. Two main approaches have been put forward. These are image-based theories and structural theories. While image-based theories assume recognition based on one or multiple viewpoint-specific representation of each objects, structural theories propose recognition based on a three-dimensional mental model against which encountered real world images are compared.

In support of a structural approach, Marr and Nishihara (1978) suggested that object recognition needs to be object-centred rather than viewer-centred as a viewer-centred theory would find it difficult to allow for the large volume of separate possible viewpoints that would need to be held in memory by each individual for each encountered object. They also argue that the mental representation of an object is not affected by the angle at which it is viewed. Biederman (1987) proposed the Recognition By Components (RBC) theory. He suggests that each object is composed of a number of basic shapes, which when fitted together form the final object. In order for object recognition to occur, the viewer must identify each individual part or geon and their relation to each other as well as to the whole object.

However, structural theories have come under criticism from researchers supporting an image-based approach to object recognition instead. Image-based studies suggest that a few familiar viewpoints are held in memory and mental rotation is used to align unfamiliar views to already held representations (Jolicеur, 1985; Tarr & Pinker, 1989; Bülthoff & Edelman, 1992; Tarr, 1995; Tarr, Williams, Hayward & Gauthier, 1998; Humphrey & Khan, 1992; Tarr & Bülthoff, 1998). Based on reaction time data obtained by both Joliceur (1985) and Tarr and Pinker (1989) it appears that unfamiliar viewpoints are examined and compared to more familiar viewpoints in order to make a judgement on object identity. Findings also indicate that once new viewpoints become familiar recognition time for these viewing angles is reduced (Tarr & Pinker, 1989), but this acquisition of new viewpoints is object specific and does not transfer to other objects (Joliceur, 1985). Tarr et al. (1998) also highlight that Biederman's (1987) RBC theory assumes that geons can be easily recognised from any angle, yet they obtained significant viewpoint effects for geons suggested by Biederman (also see Humphrey & Khan, 1992). Tarr, Bülthoff, Zabinski and Blanz (1997) later discovered that object complexity affects the magnitude of viewpoint-dependency with more complex objects resulting in longer response latencies than structurally simpler objects.

Yet, it is also clear that while unusual or unfamiliar views of an object may result in longer response times, recognition accuracy is not significantly affected by altering the direction from which an object is seen (Tarr et al., 1997). This is hardly counter-intuitive. Consider, for example the images in Figure 1.1 below. While you will likely be able to reliably identify both as pictures of a tree, you are likely much more familiar with the right image of a tree than the left. After all, unless you are a pilot or hot air balloon enthusiast, it is unlikely that you will be familiar with a bird's eye view of a tree.

Figure 1.1: Top and side view of a tree.

Many commonly encountered objects are likely to be seen in specific orientations. People do not keep upside down sofas or position a fridge with its door to the wall. It therefore follows logically, that certain viewpoints are likely to be more familiar than others, will be reinforced more frequently and will be recognised faster and more easily as a result of frequent exposure (Zajonc, 1968; Zajonc, 2001). In fact, some stimuli are so strongly orientation-dependent that we experience great difficulty making sense of them in an unfamiliar rotation. While the two faces in Figure 1.2 look nearly identical when viewed upside down, turning them upright reveals a stunning difference. Being so accustomed to viewing upright faces means that the visual system is ill-equipped to compensate for this level of rotation (Valentine, 1988). No such difficulties are observed in monkeys who encounter upside-down faces much more regularly during their treetop lives (Kendrick & Baldwin, 1987).

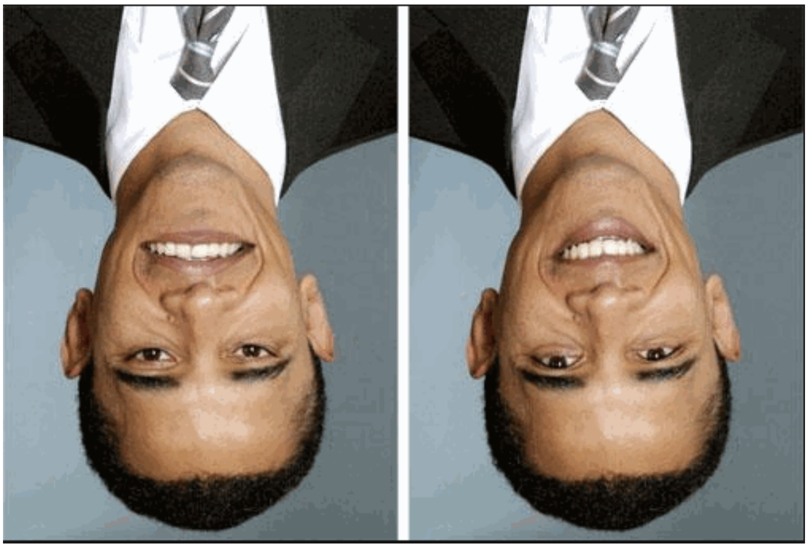

Figure 1.2: Thatcher illusion; two upside down views of different faces.

Finally, the questions needs to be posed of how useful it would be to hold a representation of each potential viewpoint of an object in memory equally strongly, when said objects are likely to be encountered in a very limited number of viewpoints in everyday life. Thus, in nine out of ten occasions, an imagine-based representation based on a handful of viewpoints will suffice for accurate object recognition. Yet, this does not exclude that a full three dimensional model of an object is accessible in memory. Srinivas (1993) found that while common viewpoints of an object did not prime unusual views of the same object, exposing participants to an unusual view significantly primed recognition of common views, clearly suggesting that both are included in the full object representation; that is an object recognition heuristic based on familiar viewpoint comparison does not exclude that full structural representations of objects are held in long-term memory. Logothesis and Sheinberg (1996) argue that both theories have merit and aspects of both need to be incorporated to fully understand object recognition. Additionally, viewpoint familiarity and multitude increase as object familiarity increases (Bartram, 1976; Logothesis & Sheinberg, 1996). Furthermore, Logothesis, Pauls and Poggio (1995) found evidence for both viewpoint-dependent and viewpoint-independent neurons involved in object recognition.

Last, but not least, it needs to be noted that object recognition does not occur merely on the basis of viewpoint but is usually aided by other diagnostic aspects such as texture and colour, which become particularly important when shape alone possesses limited discriminatory potential (Rossion & Pourtois, 2001). Additionally, objects are not usually recognised on an individual basis in a laboratory but tend to co-occur with other objects (Oliva & Torralba, 2007) and contextual cueing is commonly observed (Chun & Jiang, 1998; Olson & Chun, 2002; Bar & Ullman, 1996). This means that objects are located and recognised faster in a natural context than when they are out of place or shown without context (Chun & Jian, 1998). The same is true for objects, which commonly co-occur. When these are shown in their natural respective position [e.g. glasses below a hat] recognition speed improves (Bar & Ullman, 1996). Both objects and spatial location information are recalled more accurately when presented in an organised compared to an unorganised scene, lending further support to the importance of context (Horowitz, Lampel & Takanishi, 1969).

Gestalt Psychology

Gestalt psychology has its roots in ideas that were conceived more than a hundred years ago, yet its principles are still highly relevant today. One of the main criticisms Gestalt psychology found with traditional scientific theories was that psychology as a discipline was too concerned with investigating an object or process by dividing it into smaller parts or steps that would eventually add up to understand the whole (Wertheimer, 1938). Wertheimer (1938) argued that this method of disassembly missed an important aspect of functionality by ignoring dynamic relationships between parts. In fact, Gestalt psychology proposes that the nature of the whole cannot be accounted for by its individual pieces alone but exists beyond the sum of its parts. Wertheimer (1938) further argues that the perception of each part is influenced by the overall perception of the whole. Gestalt theory argues that each individual part needs to be understood in relation to the whole to which it belongs and that the whole itself can only be fully understood as a result of interactions between itself and its parts. It also emphasises the role of context. While traditional behaviourist views at the time have often assumed that the same stimulus will invariably evoke the same reaction (Watson, 1913; Thorndike, 1905; Skinner, 1938), Gestalt psychology suggests that perception can be radically changed as a result of circumstance.

Although Gestalt psychology is by no means exclusive to visual perception, it has offered a series of visual grouping principles concerned with perception of objects and visual scenes. These principles describe how local features are grouped together and come to be seen as a whole rather than separate entities. Gestalt grouping principles include proximity – features that are closer together will be grouped, similarity – features that are similar will be grouped, common fate – features that move in unison will be grouped, symmetry – symmetric features will be grouped, parallelism – parallel features will be grouped, continuity – lines are seen to continue in a natural direction, closure – closed shapes are perceived as wholes, and common region – features enclosed within a shape will be grouped (Rock & Palmer, 1990). Examples are shown in Figure 1.3 below. While all these principles have been experimentally tested and confirmed (Wagemans, Elder, Kubovy, Palmer, Peterson, Singh & von der Heydt, 2012), it has also been shown that some principles affect visual perception more strongly than others (Gephshtein, Tyukin & Kubovy, 2011).

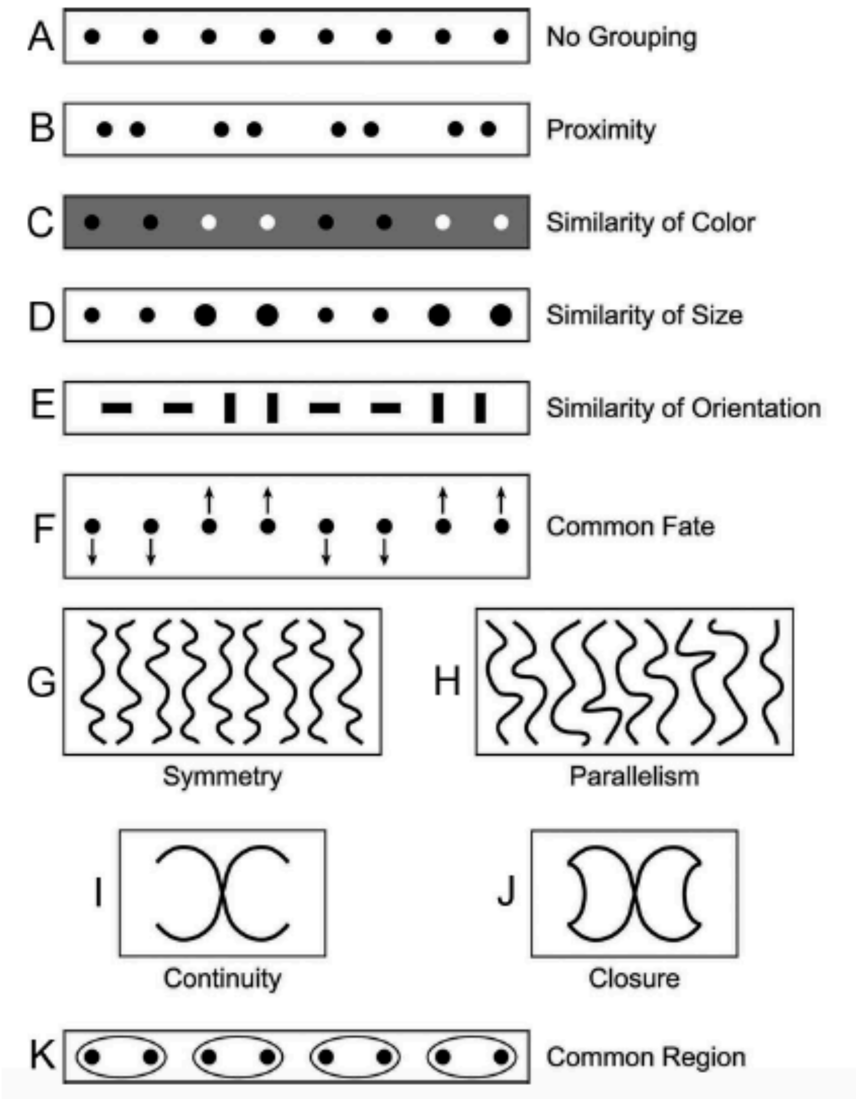

Figure 1.3: Gestalt principles of visual grouping as shown in Wagemans et al., 2012.

A further distinction is that between figure and ground. This allows the visual field to be divided into foreground and background. Under normal circumstances these are easy to distinguish such as in the image on the left in Figure 1.4 below, but the same principle has been used to create optical illusions, where figure and ground are ambiguous and perception can change rapidly between which features determine the foreground and which are part of the background, such as in the Pittsburgh Zoo logo on the right in Figure 1.4 below.

Figure 1.4: Silhouette of a tree (left) and Pittsburgh Zoo logo (right).

Lamers and Roelofs (2007) suggested that the principle of common fate could play a role in the occurrence of the Stroop effect (Stroop, 1935). In a series of experiments they moved or removed either the target colour or the distractor word after initial appearance and found that any manipulation leading to independent action of the two dimensions reduced interference. They attributed this to a lack of common fate under these circumstances. It should also be considered that this type of manipulation visually decouples the two dimensions, reducing integration of features. It is conceivable that this visual separation allows for easier mental separation. Pomerantz and Pristach (1989) also argue for the primary perception of wholes. They suggest that whole shapes are more distinguishable than their discriminating features in isolation. Findings by Pomerantz, Sager and Stoever (1977) confirm that identifying features are recognised faster when shown in context, even if the context is identical for each feature; for instance, the direction of diagonal lines is more easily identified when attached to L-shapes and a closed bracket is more easily found in an array of open brackets when surrounded by further open brackets as shown in Figure 1.5 below. As can be seen, these new stimuli derived by additional context also make use of the principles of closure, symmetry and parallelism, lending some further support to the validity of Gestalt principles of perception.

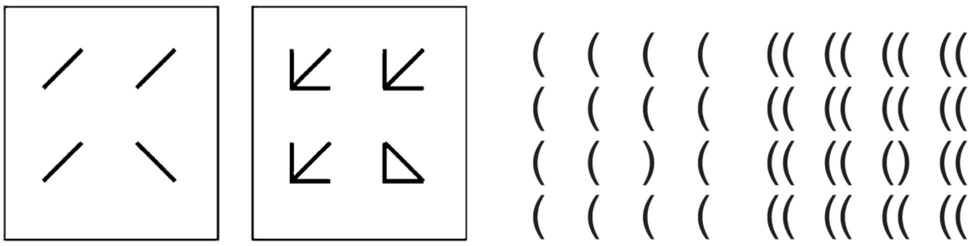

Figure 1.5: Stimuli used by Pomerantz et al., 1977.

At its core Gestalt psychology argues that while individual parts form the foundation of perceived wholes, the whole exceeds the sum of its parts and is grasped before awareness of individual features arises (Wagemans et al., 2012). Examples of this can be seen in Figure 1.6 below, which shows a series of images cleverly composed of smaller local features. Perception of the global features commonly prevails upon first glance, before local composition is examined. Gestalt psychology further proposes that while perception is primarily holistic, a continuous feedback loop exists between the whole and its parts, both of which in turn give meaning to each other. The result of this interaction is described as the emergent features of the whole as they emerge from the interplay of the separate pieces but are not themselves contained in any individual one (Wagemans, Feldman, Gepshtein, Kimchi, Pomerantz, van der Helm & van Leeuwen, 2012). Kimchi (1992) also emphasises the primacy of holistic perception but highlights the distinction between global processing and holistic processing, clarifying that the two should not be equated. In particular, holistic processing is concerned with the interrelation between global and local features, not simply the primary processing of the former. The current body of work proposes that for holistic processing to occur, local features need to be conceptually related to global features, as unrelated local features do not possess the potential to relate meaningfully to the whole. Thus, holistic perception may occur for the left picture in Figure 1.6 below, showing both a large and small portrait of Don

Quixote, but is substantially impaired for the right picture since a meaningful relationship between a skull and two little girls is much less readily established. Instead, both images are more likely to be perceived as separate entities, which coincidentally coexist as a result of featural composition.

Figure 1.6: Don Quixote (left); young girls and skull (right).

Language

Every child learning to speak a language needs an incredible set of abilities in order to succeed at this complex task. Word learning, particularly for children from Western cultures, is a unique area in language acquisition insofar as parents will always correct inaccurate use of words whereas they are prepared to let grammar mistakes slide in full confidence that those misconceptions of language rules will eventually resolve themselves. A child using ‘goed’ instead of ‘went’ is a common overgeneralisation and often overlooked, but if little Timmy were to refer to the family dog as a chair, his parents would gently, but immediately rectify the mistake (Bloom, 2000). While most children in Western cultures receive similarly extensive support and instruction when they begin to utter their first sounds, this intense reinforcement is by no means necessary to develop adequate language abilities. In fact, in some cultures children are not spoken to at all until they learn to speak at least simple sentences (Pinker, 1994) and those children are just as accomplished at developing their language as Western children are. In fact, not even visual cues are needed for language acquisition as blind children learn language at just the same rate as sighted children (Gleitman & Landau, 1985). While this may, at first, seem surprising, parental intervention can explain very little of how children pick up new vocabulary. A lot of parental teaching involves labelling objects the child is currently interacting with, such as saying 'dog' when the child is walking towards the dog. This, however, does not explain how the child knows that the parent is referring to the animal and not the mat it is sitting on, the ball it is playing with, the chair right next to it or the very action of walking. Neither does it explain how the child learns to understand abstract nouns such as imagination, friendship or poverty, nor how they grasp labels for feelings such as joy, confusion or anger. It is even less able to explain the understanding and acquisition of other types of words such as verbs, adjectives, adverbs, preposition or pronouns (Bloom, 2000). If word learning was based merely on this simplistic method of instruction, children's successful word acquisition could not be explained. When communicating with the child, parents also tend to use minimal sentence structure or single words, an approach that cannot account for the remarkable rate at which children develop their vocabulary. From the age of about 12 months to the age of seventeen children learn an average of ten new words per day (Pinker, 1994), a learning rate they never achieve again in later life.

The amazing rate at which children learn new words is one of the most stunning aspects of language. Children can learn a new word after only hearing it mentioned a few times on a single occasion (Markson & Bloom, 1997). This is particularly interesting if we consider how notoriously difficult it is to remember paired associations such as capitals or historic dates or even our friends' birthdays. But word learning may have almost nothing in common with learning associated pairs. Verbal labels are highly salient aspects of a concept and, in fact, the only information of any use to discuss it with our fellow humans, barring the presence of a physical object. Our brains are programmed to organise the world into meaningful segments and we recognise concepts before we can name them (Cohen & Strauss, 1979; Quinn, Bhatt, Brush, Grimes & Sharpnack, 2002; Needham, Ducker & Lockhead, 2005). Yet, we may never acquire words for some of the concepts we recognise. Over time, verbal labels are incorporated into a concept and becoming synonymous with it, with strongest links between the verbal and conceptual level being formed in an individual's primary language (da Costa Pinto, 1991). One important tool is the human ability to generalise from one instance to others, that is, when learning what a chair is, we have no trouble recognising different chairs even if they differ radically in shape, colour, size or design (see Figure 1.7 below). This often incredibly accurate mental classification is not easily explained and is not merely based on surface similarity or the affordances of the object.

Figure 1.7: A selection of different chairs.

Another important tool is the development of a theory of mind (Wimmer & Perner, 1983; Leslie, 1987; Wellman, Cross & Watson, 2001) or the ability to infer what others are thinking, feeling and what they are referring to. This allows children to identify more accurately what adults are talking about and facilitates acquisition of new vocabulary. It allows them to follow a conversation and infer the meaning of words that were previously unfamiliar. Rizzolatti and Arbib (1998) also argue the importance of mirror neurons in the human brain for language acquisition. They suggest that learning through observation may be a main factor in language development and functions as an incentive to actively produce language.

Although language is an important communicational tool, it may restrict conceptual thinking (Barsalou, Yeh, Luka, Olseth, Mix & Wu, 1993). While we may be fundamentally aware of concepts we cannot name in a single word (Phillips, 2004), they can seem to elude us as a result of not being labelled. If on the other hand there were a word for every possible concept, language would become infinitely more complex. In cases where no single label is readily available, words can be combined to explain the entirety of the desired concept, such as in the case of worn clothes, coloured paper or a broken television. Instead of individual labels, Lakoff (1987) discusses the idea that concepts have different variables that are filled with information to access specific instances of a concept. For example looking at size, colour and eating habits of the 'bird' concept, the information 'medium, red, eats seeds' would represent 'cardinal' whereas the input of 'large, black, eats carrion' would result in accessing the subordinate concept of 'vulture'. He argues that concepts are not pre-set but rather are constructs in working memory that draw on long-term memory information and are formed to fit the current situation. Lakoff (1987) explains that some concepts cannot be accessed without activation of other strongly related concepts (skunk – smell; diamond – valuable). This is consistent with Meyer and Schvaneveldt's (1971) view of a connectionist system being used to represent concepts; an approach in which the on-going spreading activation can also explain priming effects. Lakoff (1987; also see Barsalou, 1982; Greenspan, 1986) then argues that some features of a concept may be accessed only in dependence on context (basketball[float], when used to hold onto in water) whereas other relations become activated automatically due to frequent co-occurrence (dog[barks]).

At this point, learning concepts relating to concrete entities certainly seems possible. If you see a furry, barking entity and someone points at it and says 'dog' you are very likely to infer that this utterance is related to the furry thing and that it is called a dog. Humans are very good at understanding symbols and language is essentially symbolic. Humans are also predisposed to see the world in wholes and group features that seemingly belong together (Wertheimer, 1935; Rock & Palmer, 1990). Thus we can infer that the word 'dog' refers to the whole being and not to its fur or the sounds it is making. It is also likely that you already conceptually understand what a dog is, what it looks, feels and sounds like, you just didn't know what to call it. In this fashion new words refer to both things in the world and concepts in the mind, effectively providing a tool to link the two. Strongest links are established in the first language (da Costa Pinto, 1991), which is acquired during childhood. Yet, the primary representation remains the conceptual one held in long-term memory. Potter, So, von Eckardt and Feldman (1984) present evidence for conceptual mediation but not direct word association in second language learning; that is, words in the second language are mapped directly onto conceptual representations rather than relying on verbal translation.

Abstract concepts are much more difficult to understand. The majority of abstract concepts have no tangible counterparts in the real world. While we are able to experience some of those concepts, such as frustration, tiredness or love, others are far beyond our grasps and thus Mondays, for instance, are an exclusively human artefact. There is nothing in the natural world around us that makes Mondays distinct from Tuesdays, Wednesdays or Sundays. These concepts are almost impossible to learn from observation and therefore the majority of those words must be learnt from linguistic context. This is a continuous process where each encounter with a given word strengthens its relationship to the concept and each new context adds information to the concept entity, perhaps similar to exemplar theory of conceptual processing (Medin & Schaffer, 1978).

Bloom (2000) has argued that thought without language is possible, even that thought needs to precede words in order for language to develop. Past scientific research supports this belief (Brown & McNeil, 1966). Nevertheless, it is undeniable that language in turn shapes thought, although it could be argued that this influence is directive rather than restrictive. There is no doubt that words help us to organise the information we have and distinguish one thing from another, but we do not need words to recognise the world around us. When looking at a busy street we do not consciously label each and every object we see, every colour we perceive and every sensation we experience although it is almost certain that this multitude of concepts will be activated in our minds at least very briefly when our brains process the visual scene.

Conceptual Processing

The human understanding of concepts and categories plays a significant part in how we see the world. Categories are an essential part of everyday life. They help us make sense of the world around us and allow us to engage in inferential reasoning. While the majority of categories are agreed upon by the majority of people, they can vary depending on context (Ross & Murphy, 1999a) or current goals (Barsalou, 1983). Human beings also tend to organise their everyday life in categories (choosing what goes where in a kitchen or a wardrobe) and items can simultaneously belong to more than one category within the same domain (e.g. both a fruit and a snack; Ross & Murphy, 1999b).

The concepts into which we divide our world are intuitive, not random. We interpret the world in wholes, not parts. When we see a tree, we see the whole tree, not the stem, the branches and the leaves as separate entities (Navon, 1977). Separate processing would be too effortful and not very informative, so we group together features than seem to belong together (Rock & Palmer, 1990). In the same way, we classify things into meaningful categories, commonly based on function. We don't, for instance, group things based on whether they are bigger or smaller than a person. We don't group together all things made of metal, all round things or everything that is hollow. Yet, a group of broken objects, even if these vary greatly, does not seem incoherent. Seemingly nonsensical classifications are based primarily on perceptual aspects of items such as colour or size, rather than their underlying, conceptual properties such as whether they are man-made or natural, dangerous or harmless or what their individual function is. Schreuder, Flores d'Arcais and Glazenborg (1984) suggest that although both perceptual and conceptual similarities can lead to independent priming effects, conceptual classification is undoubtedly preferable and more informative than perceptual classification. In everyday life, basic level names allow just the right amount of informativeness and distinctiveness (Murphy & Lassaline, 1997). By calling a thing a dog (rather than a collie or an animal), we distinguish it from other animals, such as cats and wolves and while also being able to draw sufficiently general and reliable inferences about its nature and behaviour, which could be applied to both collies and terriers.

A number of theories have been put forward to explain how we develop conceptual understanding and how concepts are formed. The classical view of concepts was first published almost a century ago (Hull, 1920). It states that a candidate in order to be included in a category must have all the properties of that category and that likewise a candidate that has all the properties will automatically be seen as belonging to that category. However, the classical view fails to account for typicality effects, graded membership judgements (Schmidt, 1996; Rosch, 1973; Barsalou, 1983) and a lack of transitivity (Hampton, 1982a, b). New theories have followed to improve upon the old ideas. The most influential contestants are prototype theory (Posner & Keele, 1968) and exemplar theory (Medin & Schaffer, 1978). Prototype theory suggests that through encounter of many members of a category a mental representation of a prototype (a best member) is formed which then acts as the basic concept to which each new encountered instance is compared. Category inclusion hence depends on similarity to and shared properties with the representation of the prototype held in long-term memory (Smith, Osherson, Rips & Keane, 1988). But this approach forces the question what similarity actually means and whether comparisons are made on perceptual or conceptual factors (Eysenck & Keane, 2005). It furthermore remains unclear how prototypes are created for ad hoc categories (e.g. ‘things to take with you in case of a fire’ [Barsalou, 1983]), negative categories (e.g.

‘not a giraffe’) or how abstract concepts (e.g. ‘love’ or ‘creativity’) might be formed (Pinker, 1997).

Exemplar theory on the other hand suggests that each encountered instance of an object adds a new version of that concept to long-term memory, which means that every exemplar that is encountered becomes a part of the concept so that the conceptual representation is constructed from a collection of exemplars (Medin & Schaffer, 1978; Nosofsky, 1988). While this view is more flexible and allows for variability of concepts, it seems to assume prior knowledge about concept properties and it appears impractical in that it cannot explain how in retaining a memory of each encountered member of a category memory overload could be avoided. Although there appears to be an initial perceptual bias based on shape in both children and adults when attempting to categorise novel objects (Bloom, 2000), this basic level of information is used only in the absence of other relevant information. If the function of the object becomes known, function appears as a much better indicator of object category than shape (Lin & Murphy, 1997). In addition, while functional features are more important to be preserved for man-made objects, it is underlying, internal features that determine category inclusion for natural objects (Barton & Komatsu, 1989; Medin, Lynch & Solomon, 2000).

While concepts are closely related to their verbal counterparts, they can be accessed and understood without the corresponding label being activated (Brown & McNeill, 1966). Additionally, there is substantial research in infant populations, which evidences conceptual processing without the acquisition of language. Phillips (2004) found that infants can understand different concepts without yet having acquired [or in fact ever acquiring] the words to name them. Cohen and Strauss (1979) reported that signs of conceptual processing can be observed from the age of

24 weeks and is clearly expressed in 30-week-old babies. At the age of between three and four months Quinn, Yahr, Kuhn, Slater and Pascalis (2002) found evidence of gender categorisation as well as gender preferences for faces based on the gender of the primary caregiver. Needham et al. (2005) furthermore present findings suggesting that three to four months old infants are capable of conceptual abstraction to form basic categorical representations and visual grouping of a scene by means of exemplar exposure. These findings highlight the fundamental importance of conceptual understanding in human processing.

Levels of processing

The ability to memorise and organise information meaningfully is one of our most valuable assets for survival. If we had no memory, the world around us would be meaningless. We would be unable to retain any information we acquire and each encounter with a concept would effectively be the first. Without our ability to remember, we would not know our names, where we lived or how we could come by food and find shelter. Without memories our friends and loved ones would be strangers. In short, we would be completely incapacitated and unable to function or survive. Equally, if left without the human ability for information processing we would be unable to make sense of the world around us or purposefully interact with it.

An important relationship is that between objects, their names and their pictorial representations. It is a relationship forged from an early age when children learn to understand and label new concepts from pictures, books and their own drawings as much as through observing the same objects in real life. Over time this relationship becomes so strong that even a very abstract drawing of a thing or a word that describes it can evoke a mental image as strong as seeing the actual object.

Compare the images in Figure 1.8 below. While one is a photograph, the other is a very simple line drawing. Yet both are equally effective in activating the ‘dog’ concept.

Figure 1.8: Photographic (left) and abstract (right) representation of a dog.

The more we are able to understand the cognitive processes related to memory and information processing the more effectively can we use our mental capacities. In early days memory was seen as a set of structured boxes, consisting namely of sensory memory, short-term memory and long-term memory (Atkinson & Shiffrin, 1968; 1971; Shiffrin & Atkinson, 1969). Around the same time, the levels of processing framework was proposed (Craik & Lockhart, 1972). Although the theory retained the idea of short and long-term memory it stated that there must be additional factors leading to better or worse information retention. The theory distinguishes three main levels of processing: structural, as being the most shallow one (i.e. what is the pattern of consonants and vowels in a word; is the word written in capitals or not), phonetic (i.e. does the word rhyme with another word) and semantic, as the deepest level (i.e. does the word fit into a given sentence; with what adjective could the word be described). In later years, self-referent encoding was added as an additional highly effective level leading to even deeper processing as a result of both elaborative and organisational mechanisms (Klein & Loftus, 1988). Since levels of processing were first discussed, neurological evidence has been found, showing that the mental processes associated with these levels take place in different regions of the brain and thus indeed appear to be structurally different (Nyberg, 2002).

The core of the theory states that the more deeply new information is analysed or processed the better will it be recalled later (Craik & Lockhard, 1972). This means that words processed on a deeper level are more likely to leave a deeper 'trace' in the brain and are thus also more likely to be remembered. A series of experiments was carried out to support the levels of processing theory (Craik & Tulving, 1975). In altogether ten experiments Craik and Tulving (1975) found a wide range of evidence that semantic processing helps to significantly improve memory performance. They also found that for higher levels of processing (phonetic and semantic) a positive answer (e.g. "Does the word rhyme with 'wild' – 'child' - yes"; "Does the word fit into the sentence: 'He met a _ on the street' – 'friend'-yes") also increased likelihood of retention. It was argued that this occurred due to the greater richness of the material if question and answer could be positively combined and integrated into an existing knowledge structure.

In order to obtain satisfactory evidence for incidental learning and levels of processing, participants needed to be unprepared for a recall test, believing that their only task was to determine whether a word was written in capitals or not, whether it rhymed with another word or by what adjective it could be described. If subjects were prepared for the recall test they might attempt to use different methods of memorising, which could interfere with the results. It was found later that experiments in which participants were aware of the subsequent recall task produced results that were still very much alike (Craik & Tulving, 1975). It was also found that even in a condition in which participants were paid for recalling words from the structural section there was little variation in the outcome. Participants explained that items from the semantic category simply seemed easier to remember. These findings provided further evidence for the impact of depth of processing.

It should, however, be taken into account that levels of processing cannot be considered the sole determining factor for memory performance. Research has found a number of other factors that impact retention likelihood. There is evidence that, for instance, orthographically distinct words are remembered more readily (Kirchhoff, Shapiro & Buckner, 2005), although this collides with the levels of processing theory as orthography would be considered a low level of processing. It might be related though to findings from Craik & Tulving (1975) who in one experiment discovered that the complexity of a sentence in the semantic condition noticeably enhances later recall. This may relate to either richness of information or to increased rehearsal times for longer sentences. The precise role of orthographic distinctiveness will be discussed later.

While rehearsal has often been used as one of the main means of memorisation, it is a shallow level of processing according to Craik and Lockhart's theory (1972). A study was devised in which a set of words was read to participants and they needed to always remember the most recent word starting with the letter 'd'. Depending on how many words stood between the 'd-words' rehearsal times could be manipulated; so for example in the set of 'dog – house – dome – garden – sea – table – dream' the word 'dome' was rehearsed considerably longer than 'dog'. It was found that rehearsal times had no significant influence on subsequent likelihood of stimulus recall (Craik & Watkins, 1973).

But what do those findings truly reveal? Do subjects adhere strictly to instructions and thus words do not get processed beyond the level of the assigned task or do participants make a conscious effort to recall as many items as possible but don't know how to go about it? Findings by Nelson, Reed and McEvoy (1977a) cast doubt on participants' ability to select an exclusive encoding strategy as they reported activation of both sensory and semantic codes regardless of encoding instructions. Moreover, other factors may interfere with encoding such as emotional valence of stimuli. It was found to impact recall even if valence is unattended, with positively valenced words recalled better for physical encoding conditions and both positively and negatively valenced items recalled more accurately under semantic encoding instructions as reported by Ferré (2003).

Following further research it turned out that levels of processing were never as clear-cut as they were initially made out to be. Manipulating the recall conditions of Craik & Tulving's (1975) experiments produced a significant change in results (Morris, Bransford & Franks, 1977). Instead of using a free recall test they gave participants a rhyming recognition test, which resulted in better recall scores for the rhyme words. Accordingly Morris et al. (1977) argued that the effectiveness of memorising stood in relation to the retrieval task given at a later point. But Craik (2002) pointed out that "the combination of semantic encoding and semantic retrieval yielded a substantially higher level of recognition than the rhyme-rhyme combination." Furthermore the whole concept of processing information on different levels might not be the most realistic as words are automatically processed on a semantic level when meaning is accessed during reading as shown in the Stroop effect (Besner & Stolz, 1999).

Dual Coding Theory

Dual coding theory was first comprehensively formulated by Paivio (1971, 1986). It distinguishes two separate processing pathways, one for verbal and one for non-verbal information. While the non-verbal route is direct, fast and automatic, verbal processing is concerned with deliberately and intentionally encoded material, requiring focussed attention and thus resulting in slower processing. Paivio (1971, 1986, 1991) emphasises that the verbal/non-verbal distinction is not a distinction of modality and that both formats can be applied across modalities. The visual system can process both verbal material through reading text or looking at pictures; auditory information may include speech as well as non-verbal communication through sound, such as screams, cries, laughter or whistles and haptic input can be derived both from producing a verbal output through pen movement while writing or active manipulation of objects. Other modalities such as the gustatory, olfactory and affective systems, however, are non-verbal by nature and need to be processed as such. Paivio further highlights that the verbal and non-verbal systems function independently and represent two separate systems, which map onto each other, representing both human language and the non-articulate knowledge of the world around us (Sadoski & Paivio, 2004). According to the dual coding assumption, information derived from the two channels produces an additive effect; that is, providing the same information through a verbal and non-verbal pathway leads to deeper encoding and a more lasting memory trace than input through only one route. This has been evidenced by findings by Paivio (1975) of enhanced memory for items when presented in both verbal and non-verbal form even at 0 lag; an effect which is not obtained when the same format is presented twice. Additive effects of repeated same format presentation only occur following a several item lag (Paivio, 1975). Paivio (1991) argues that the same should be true of separate modalities; that is, reading and listening to the word 'dog' should result in better recall than input through a single modality (Beacham et al., 2002). Dual coding also assumes that while some stimuli are more suited to one pathway over another, this does not mean that they cannot be processed through either. Verbal stimuli may be processed through a non-verbal route by means of mental imagery and pictures can be processed verbally through naming (Sadoski & Paivio, 2001). Since, however, their primary processing channel is still open, this means that information will effectively be processed through both channels if the less likely route is activated by encoding mechanism, therefore leading to dual encoding of information. This effect has been experimentally confirmed by a series of studies (Paivio & Csapo, 1973; D'Agostino, O'Neill & Paivio, 1977; Durso & Johnson, 1980). D'Agostino et al. (1977) reported that while levels of processing effects work well on words, they are not observed with picture stimuli. They argue that structural and phonemic manipulations of picture stimuli will necessarily result in retrieval of the verbal correspondent, therefore eliciting dual processing for these items. In addition, Durso and Johnson (1980) found that when picture and word stimuli were presented under verbal encoding instructions, picture superiority was observed. In contrast, when non-verbal encoding was required, word superiority was found. When a referential task was required, such as judging the object's size or function, no difference in recall scores was observed between the two. This is also supported by findings presented by Ralph, Graham, Patterson and Hodges (1999) who argue that semantic information is extracted from both words and pictures in a highly similar fashion. The dual coding framework suggests that stimuli of greater concreteness will be processed faster as they will evoke a complex mental image more easily than abstract concepts. This is in accordance with findings showing that more concrete words can be imaged more easily (Richardson, 2003) and will be recalled with greater accuracy (Miller, 1968).

The effectiveness of dual coding has also been evidenced in studies of learning. In accordance with Paivio's (1971, 1986, 1991) prediction, Beacham et al. (2002) found that information is retained best when presented as spoken text alongside illustrative diagrams, but is less efficiently processed through the same modality such as presenting diagrams along written text. Mayer and Anderson (1991) confirmed that students performed best when given both visual and verbal instructions simultaneously but not consecutively. Simultaneous presentation also showed greater benefit than presentation of each format in isolation. Chun and Plass (1996) reported that presenting both visual and verbal material was more effective than verbal material alone for second language learners. While these principles generally apply, they may be mediated by other factors such as spatial ability (Mayer & Sims, 1994) or individual learning style (Reinert, 1976). Developmental studies reveal that the advantage derived from dual coding only occurs when processing mechanisms have become more refined. While both topically related and unrelated images slow reading speed of words in second and third graders (Willows, 1978), illustrations aid understanding of text segments in middle school aged children (Hibbing & Rankin-Erickson, 2003), particularly for children with low imagery ability. Students reported that looking at accompanying illustrations helped them focus more closely on the content of material rather than concentrating on reading and text comprehension.

Picture Superiority

Another phenomenon suggesting the presence of conceptual processing without intention is the picture superiority effect which has repeatedly shown superior performance on recall of pictures over words (e.g. Shepard, 1967; Blanc-Brude & Scapin, 2007, Stenberg et al., 1995) to the extent of producing above chance performance in a cued recall task 17 years after a single exposure (Mitchell, 2006). Plaue, Miller and Stasko (2004) found that information is retained better when presented in pictorial format, even if this involved learning to interpret non-verbal information symbolically such as using the height of a kite in the sky as an indication of cost or a sailboat travelling along the horizon to indicate the time of day. The discovery that pictures and words are processed differently has long been established. Picture naming has reliably been shown to take longer than naming verbal counterparts (Carr, McCauley, Sperber & Parmelee, 1982). This effect has been argued to arise from the fact that while words have direct access to lexical information, picture naming involves the active retrieval of verbal information, minutely delaying the naming response (Theios & Amrhein, 1989). However, when the required response task is altered so a decision must be made on a semantic or conceptual level, such as completing a categorisation task, pictures reliably lead to increased performance compared to words (Friedman & Bourne, 1976). It has accordingly been suggested that while pictures open up the possibility of fast access to semantic information and somewhat delayed access to verbal labels, the reverse is true of words (Smith & Magee, 1980). Contrarily, Amrhein, McDaniel and Waddil (2002) reported that conceptual decisions can be made equally quickly about either pictures or words, suggesting that conceptual activation can be derived from either format with equal effectiveness.

Nevertheless, the majority of studies seem to indicate that information contained in pictures may be richer than its linguistic equivalent. This effect has been explained by a number of theories including Paivio's (1971) dual coding theory, which suggests that information is processed and encoded via both verbal and non-verbal pathways and that pictures will derive a greater benefit since they are more easily channelled into these pathways than words which will not as readily evoke a mental image that may equal that induced by a picture in complexity. Furthermore pictures may be more adequately processed by the visual system than written stimuli (Stenberg, 2006) and may lead to a greater spread of activation of semantically related concepts (Stenberg et al., 1995). Stenberg (2006) argued that both perceptual and conceptual factors contribute to the picture superiority effect, but states that conceptual factors play a larger role. Mintzer and Snodgrass (1999) discovered that while pictures were significantly less likely to be recognised when shown as words during recognition, words suffered substantially smaller losses when this pattern was reversed. They argue that this supports a distinctiveness explanation for pictures rather than a dual coding account. However, findings are also consistent with access to richer information and deeper processing as a consequence (Craik & Lockheart, 1972). The available data suggest that pictures contain more complex information than words alone. This leads to a greater processing demand and subsequently to deeper levels of processing (Park & Mason, 1982). Yet, more complex pictures do not seem to have an enhancing effect over simpler ones (D'Agostino et al., 1977). A simple line drawing can be as effective as a photograph; the brain being much better adapted to filling in the blanks in pictures than converting letters into mental representations (Snodgrass & Vanderwart, 1980). Looking at both visual and semantic relatedness of words, Job, Rumiati and Lotto (1992) found that both aspects were successful in capturing attention and producing interference, resulting in slower categorisation judgements of items being the same or different. That is words, which resembled each other visually were equally confusable as words, which did not share visual similarities but resembled each other conceptually. Finally, pictures lend themselves to parallel processing substantially better than text, which by its very nature must always be processed sequentially (Neisser, 1967), although more recently eye tracking evidence has provided evidence suggesting that some parallel processing of text may also occur during reading (Starr & Rayner, 2001; Reilly & Radach, 2006; Engbert, Nuthmann, Richter & Kliegl, 2005).

More advanced knowledge regarding conceptual activation in picture and word processing has been obtained from the picture word interference task (Costa, Alario & Caramazza, 2005; Abdel, Rahman & Melinger, 2007). Participants are asked to name a series of pictures while simultaneously ignoring a verbal distractor superimposed upon the picture. It is commonly found that while categorically related words (dog-cat) hinder picture naming, semantically related words (dog-collar) facilitate picture naming (Costa et al., 2005; Abdel, Rahman & Melinger, 2007). Abdel, Rahman and Melinger (2007) also reported interference in picture naming of groups of both categorically or semantically related pictures, offering further evidence for conceptual activation. Costa, Mahon, Savova and Caramazza (2003) suggest that both superordinate and subordinate conceptual levels can act as cues; that is, both 'animal' and 'collie' can act as cues for the 'dog' concept. They further suggest that distractors from the same category cause added interference and cannot be dismissed based on superordinate categorisation. Same category distractors are located more closely together in the semantic network and supressing related distractors incurs greater cognitive effort than suppressing unrelated distractors. In effect, it is easier to distinguish a dog from a truck than a dog from a cat. DeZubicaray, Wilson and McMahon (2001) propose that a number of factors contribute to the semantic interference in the picture word task, including both conceptual and phonological processing, selective attention and response inhibition. Findings presented by Nelson, Reed and McEvoy (1977b) support automatic activation for direct phonemic access for words, but not pictures. However, on balance, Willems, Özyürek and Hagoort (2008) argue that semantic information from both pictures and words is processed in a highly similar fashion and integrated into existing knowledge structures and context in much the same way, with the same pattern in brain activation observed for extracting semantic information from either verbal or non-verbal material. Both words and pictures also benefit equally from longer exposure time and longer inter-item breaks allowing for extended rehearsal (Tversky & Sherman (1975).

Top-down versus bottom-up Processing

During processing of visual information, two main principles are employed to make sense of the input material: Bottom-up and top-down processing (Navalpakkam & Itti, 2006; Awh, Belopolsky & Theeuwes, 2012). Bottom-up processing is primarily stimulus driven and is employed when highly salient stimuli capture attention involuntarily. Information then needs to be interpreted based on visual information so a conclusion can be drawn about the nature of the stimulus and whether any action needs to be taken in response to it, for example a fight or flight decision if the object signals potential danger. In contrast, top-down processing refers to goal-directed action where observed stimuli are compared to a searched for target and attention is directed only to matching features. That is, features are accessed from long-term memory leading to a state of pre-activation and are then actively searched for in the visual field allowing them to capture attention upon detection. In short, while bottom-up processing is stimulus driven, top-down processing is data driven (Kimchi, 1992). Kinchla and Wolfe (1979) have suggested that neither bottom-up nor top-down processes occur exclusively but that processing starts from a middle level before proceeding simultaneous upwards and downwards spreading to global and local features alike. Other findings, however, have argued against this view, suggesting a global processing primacy (Navon, 1977; Stirling & Coltheart, 1977). Theeuwes (2010) describes that initially visual stimuli are processed through a bottom-up route until an outline of the visual scene has been established. While this happens very rapidly, it is only after the initial visual map formation that top-down processing begins. This goal directed type of processing allows detailed examination of the scene and local features within it to extract the sought after information. These processes are reflected in predominantly prefrontal activation for top-down processing situations and parietal activation for bottom-up processing (Buschman & Miller, 2007).

While pictures generally contain richer information, they also retain more room for interpretation and the meaning contained in them is not always as clear-cut as it is for words (Bloom, 2000; Bub & Masson, 2006). Words are uniform labels and are interpreted and understood in very similar ways for everyone who hears or reads them. If a word is familiar, it does not require additional explanation and we usually understand what a word refers to without being explicitly told. That is, words are mostly subject to top-down processing. A different pattern, however, emerges for pictures. While in the absence of any knowledge we interpret pictures on the base of what they look like, the shapes, the colours and the relations between depicted entities, having information about what the picture was intended to show can play a large part in what we see. That is, images can be more ambiguous and can be processed either through bottom-up or top-down route. Imagine, for example that I was going to draw a circle with a number of spikes surrounding it as in Figure 1.9 and showed it to you.

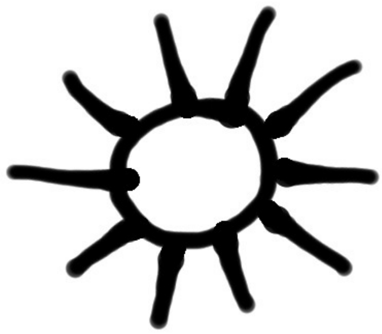

Figure 1.9: Circle surrounded by a number of spikes – example of ambiguous drawing.

Based on your previous experience with similar pictures you may think that I was attempting to draw the sun since drawing a circle with spikes is a common way of doing so. If, however, I told you that I had intended to draw a sleeping hedgehog your perception of the picture may change. You are now much more likely to see a hedgehog than to see the sun when looking at my drawing. You are also more likely to describe the picture as a sleeping hedgehog to another person if they asked you about it. In fact, you would probably completely dismiss your earlier interpretation, that is, you would be unlikely to say to another person that the picture looks like a sun but was intended to depict a hedgehog. Instead, you would simply say that it is a hedgehog. This strong effect for knowledge of intent comes about because pictures are man-made objects and as such we expect their nature to be intentional. Their most important function is to convey something to the observer and to represent in themselves the message its creator wanted to communicate. Naturally, this is true much more for abstract or ambiguous drawings than it is for pictures that are easier to interpret, such as detailed portraits or photographs. So while you may be convinced of my interpretation of a sleeping hedgehog, you will probably believe that Figure 1.10 is a drawing of three dogs (or maybe even collies if you happen to be familiar with the physical characteristics of collies) even if I told you that it was my intention to draw a line of trucks. The pictures resemble dogs much more than they do trucks and at the very best, you might be confused about either my drawing skills or my ability to tell a canine from a large vehicle. This is because, as already stated, most pictures we encounter are drawn to resemble the concepts they were intended to represent and thus contain highly informative visual cues.

Figure 1.10: Portraits of three collies.

Mental Imagery

Mental imagery refers to the process of creating a vivid mental picture of an object. The ability to vividly imagine objects and ideas is a key ingredient for creativity and has been found to be higher in more creative individuals such as artists or scientists (LeBoutillier & Marks, 2003). Additionally, people with high capacity for producing mental imagery have an increased likelihood to recall their dreams on more frequent occasions (Hiscock & Cohen, 1973). Imagery is a continuous process of conceptual activation as new and old information is processed. Imagery instructions are also commonly used to enhance recall (Pressley, 1976; Craig, 1973). Imagery has been found to be an effective memory aid in adults, including both deaf and blind individuals (Craig, 1973), with better recall accuracy recorded for high imagery compared to low imagery words. Pressley (1976) also reported an effect of imagery on content recall of short passages of text in eight year olds. In addition, Marks (1973) confirmed that imagery effects apply to pictures as well as verbal material. Imagery training has even been found to be effective in improving memory for everyday information such as story telling and appointments in patients with mild cognitive impairment (Kaschel, Sala, Cantagallo, Fahlböck, Laaksonen & Kazen, 2002). Emotional valence has also been identified as a factor in imagery with both positive and negative material benefiting more from imagery instructions than neutral stimuli (Holmes, Mathews, Dalgleish & Mackintosh, 2006). Furthermore, Eich (1985) reported that imagery can be used to either enhance or eliminate context-dependent memory (Godden & Baddeley, 1975). When participants were asked to imagine an object within their current surrounding, context dependent memory was found. Yet when participants were instructed to imagine the same object in isolation, no effect of surroundings was observed. Finally, mental imagery can increase or decrease the effect of stereotyping (Blair, Ma & Lenton, 2001) and even create false childhood memories (Pezdek, Blandon-Gitlin & Gabbay, 2006).

A number of theories have been put forward regarding the nature of mental imagery. Structural theories propose that mental images possess the same spatial and pictorial properties as real life physical objects and are a direct representation of visual input (Kosslyn, 1980; Kosslyn, Pinker, Smith & Shwartz, 1979). Functional theories propose that the formation and transformation of mental images contribute directly to object recognition by activating already held representations of the object in question and comparing it to the current visual input (Shepard, 1981; Shepard & Cooper, 1982). Finally, interactive theories propose that imagery itself contributes to on-going perceptual processes and is integral in object recognition (Segal & Fusella, 1970; Finke, 1986). A long-standing debate has addressed whether imagery elicits proper mental images or simply activates abstract presentations similar to language processing (Anderson, 1978). Thus, the question is whether a full mental representation similar to a photograph is constructed in the mind or whether a relevant propositional representation is established. In response, Finke (1985) suggests that the true nature of mental imagery likely lies between the two. Farah, Hammond, Levine and Calvanio (1988) present findings indicating that mental imagery encompasses both visual appearance and spatial location components of an object in a visual scene. Spivey and Geng (2004) also observed eye movements when examining mental images which appear to access specific locations even when the scene is no longer physically visible. Further evidence for the engagement of perceptual mechanisms in imagery comes from McDermott and Roediger (1994). They report that when participants are shown words and asked to imagine the corresponding picture, priming effects are present on a picture fragment identification task, but not a word fragment completion task. In contrast, when pictures are shown and participants are asked to visualise the verbal label, priming effects occur on a word fragment completion task, but not a picture fragment identification task. More recently, Ganis, Thompson and Kosslyn (2004) confirmed highly similar brain activation patterns for both mental imagery and visual perception, although some processing differences were implicated in sensory perception areas.

Salience, Bizarreness and Orthographic Distinctiveness

An important factor in the recall of information is the level of salience of a stimulus. The definition of salience is generally based around the capacity to stand out from the general environment (Guido, 1998). Guido (1998) suggests that there are three main ways in which salience can be achieved, which are borrowed from Gestalt psychology. The first principle is that of figure and ground. Objects in the foreground are more likely to capture attention and are more likely to appear salient in the visual field. The second in the principle of unusuality, which relates to objects that violate prior knowledge or expectation, as well as pattern disruption. For instance, a filled blue circle will be highly salient in a display of outlined red squares. Thirdly, there is the principle of domination. Domination could occur on a number of different dimensions such as size (being substantially larger or smaller than surrounding objects), colour (being substantially brighter or darker than surrounding objects) or loudness, resulting in prominence over other targets competing for attention and increasing the likelihood of capture (Töllner, Zehetleitner, Gramann, & Müller, 2011).

Guido (1998) furthermore proposes a distinction between stimuli which are in-salient and those that are re-salient. He defines these as being processed either through a bottom-up or top-down process. Hereby, in-salient stimuli are those, which are incongruent with a schema held by the perceiver and therefore need to be processed through a bottom-up route while re-salient stimuli are in line with the perceiver's goals and are processed through top-down mechanisms. He further equates these processes to either incidental learning, where the person has no need or desire to obtain information and makes no conscious effort to do so, but attention is nevertheless drawn to a stimulus as a result of (in-)salience while in the alternative scenario a person is actively searching for information in a goal-directed action and objects capture attention through (re-)salience which is established when the object is found to meet search criteria.

Other factors capable of increasing salience include emotional valence (Osbourne, 1974; Ferré, 2003), bizarreness (McDaniel & Einstein, 1986) or orthographic distinctiveness (Zechmeister, 1972). The impact of bizarreness or distinctiveness of stimuli is a now commonly observed effect in memory research. This refers to stimuli, which stand out against a background of less distinctive items and exposure to which results in higher recall rates compared to common items. Mostly the effect is investigated using verbal stimuli (McDaniel & Einstein, 1986; McDaniel, Einstein, DeLosh, May & Brady, 1995; Riefer & LaMay, 1998) but comparable results have also been observed using picture stimuli (McDaniel, Einstein & Lackey, 1989; Nicholas & Marchal, 1998). Yet, Hauck, Walsh and Kroll (1976) found that common images were processed faster and bizarre items did not benefit recall. A bizarre item may refer to a sentence such as 'He stuffed raw eggs inside his shoes.' In contrast, a common sentence may read 'He stuffed his socks into his shoes.' McDaniel and Einstein (1986) present one of the earliest investigations of the effect but research has been extended far beyond the discovery of the initial memory advantage. More recently Westerbeek, van Amelsvoort, Maes and Swerts reported that atypically coloured objects such as an orange broccoli or green meat where recalled better than typically coloured objects. They attributed this effect to item distinctiveness. Nevertheless, they did remark that more processing time was allocated to atypically coloured targets, which may have impacted improved recall. Alternatively, this could have merely been an artefact of the very nature of these stimuli. The atypical colouring could have elicited conflict with already held mental representations of these object leading to increased processing demands and more time being allocated to resolve this conflict. Alternatively, items may have just been more difficult to recognise. With colour acting as an important discerning factor in object recognition (Rossion & Pourtois, 2001), identification of atypically coloured objects would naturally be impaired and require greater effort during processing. Slower processing of atypically coloured objects has also been observed in Stroop type tasks (Naor-Raz & Tarr, 2003). In fact, in some instances simply highlighting what makes items distinct can lead to an increase in recall accuracy. Thus, both

Epstein, Phillips and Johnson (1975) and Begg (1978) reported that similarity judgements of fundamentally different items (e.g. a cat and a piano) as well as difference judgements of inherently similar items (e.g. a peach and a nectarine) yielded better recall at test than similarity judgements for similar items and difference judgments of different items. This suggests that focussing on what makes similar items distinct and different items similar may lead to deeper conceptual processing and leave a more salient memory trace and focusing on obvious attributes.

Numerous studies have put forward the argument that bizarreness effects only occur if bizarre items are shown in contrast with common items (McDaniel et al., 1995; Thomas & Loftus, 2002; Geraci & Rajaram, 2002). That is, bizarreness is limited to the list context and is contrasted only with the list content rather than with existing knowledge about what constitutes a bizarre stimulus. When all items in a list are bizarre, recall is equal to common items. McDaniel et al. (1995) attributed this to increased salience of bizarre items in comparison to common ones. Of course, this might be due to limitations of recall capacity rather than a lack of an impact of bizarreness. Other researchers have suggested that the effect of bizarreness arises from an encounter with the unexpected. That is, bizarre stimuli benefit from the element of surprise making them more memorable as a result of violating existing schemata and not readily fitting into an established knowledge base (Hirshman, 1988; Hirshman, Whelly & Palish, 1989). In line with this explanation, Riefer and LaMay (1998) suggest a storage-retrieval hypothesis. They propose that while common stimuli are more readily stored and more easily integrated into existing knowledge, bizarre items stand out and are therefore more easily retrieved, leading to the observed recall advantage. That is a single red object in a sea of green objects is easier to pick out than a dark red object in a multitude of other shades of red. Hertel and

Ellis (1979) have argued that while bizarre items are well preserved in an immediate recall test, they perform much worse at a delayed test. Their findings further suggest that bizarre items are retained in an abstract form and are almost never produced verbatim. They attribute this to a lack of integration of bizarre items into existing knowledge due to their lack of fit into established schemata. They therefore propose that this data supports a constructive approach to memory based on incorporation of knowledge and schema integration.

Similar effects have been observed not only with conceptual bizarreness but also orthographic distinctiveness (Hunt & Elliot, 1980), that is words whose surface features look distinct as a result of unusual spelling such as being made up from a distinctive combination of letters or being unusually long. These orthographically distinct words are subject to better recognition (Zechmeister, 1972) but have also been found to derive a benefit in free recall tests (Hunt & Toth, 1990). They are furthermore less likely to be confused as targets when presented as distractors (Zechmeister, 1972). Hunt and Mitchell (1982) investigated both conceptual and orthographic distinctiveness of words. They concluded that while conceptual distinctiveness aids word generation and retrieval processes, orthographic distinctiveness mostly facilitates items recognition. In contrast, Konkle, Brady, Alvarez and Oliva (2010) argued that the level of conceptual distinctiveness is a better predictor of recognition accuracy than perceptual distinctiveness. They used both wide and narrow categories, where category members were either similar or diverse; for example, instances of the ‘animal’ category would be more conceptually distinct than members of the ‘tree’ category. Thus, participants could more reliably remember whether they had previously been shown a picture of an elephant or a mouse than whether they had seen a maple or a sycamore. It has also been reliably proven that while bizarreness and orthographic distinctiveness appear similar at first glance, they are separate effects and occur independently of each other as well producing an additive effect when combined (Gounden, Cerroti & Nicolas, 2017). Both effects independently contribute to a recall advantage and separate brain regions are activated for bizarre and orthographically distinct items (Kirchhoff et al., 2005).

Furthermore, Einstein et al. (1989) reported that bizarre items are also susceptible to task interference effects and can even override other existing effects. For instance, orthographically distinct words can disrupt categorical processing and reduce inter-item cueing, resulting in orthographically distinct words being recalled as stand alone items from a list of targets (McDaniel, Bahill & Bugg, 2016). In addition, orthographically distinct words are less prone to order effects (McDaniel, DeLosh & Merrit, 2000). Yet, the impact of distinctiveness is reduced when words are written in capitals rather than lower case letters, suggesting that the more homogenous distribution of letters in capital letters clouds orthographically distinct patterns (McDaniel, Bahill & Bugg, 2016). Alternatively the effect might be diluted as a result of less frequent use of capital letters. The effect of bizarreness persists under different encoding instructions, occurring for both imagery and verbal encoding conditions (Worthen, 1995).

Finally, Gounden and Nicolas (2012) reported that bizarre items do not benefit from better recall as a result of increased exposure time. They varied stimulus exposure between 250ms and 3000ms and obtained similar results for each exposure duration. Stimulus viewing time affected neither the occurrence nor the magnitude of the bizarreness effect, suggesting that it is extremely unlikely to be a determining factor. Similar results were presented by Worthen, Garcia-Rivas, Green and Vidos (2000), who concluded that cognitive resource allocation could not account for the recall benefit of bizarre items. Fine and Minnery (2009) found that more salient stimuli produce higher accuracy in location memory tasks even when eye fixation period is equal to non-salient items. However, a determining factor, which has been highlighted, is participants' test awareness (Smith & Hunt, 2000); that is, explicit memory instructions are needed both for the bizarreness effect (Nicolas & Marchal, 1998) and orthographic distinctiveness (Geraci & Rajaram, 2002) to occur reliably.

Models of Word Recognition

A considerable amount of research has been devoted to the investigation of written word recognition and a variety of models have been developed to explain the processes involved. While initial theories stipulated that word recognition is based upon the entirety of a word's appearance rather than its components (Cattell, 1886), this approach soon lost support and theories based on individual letter identification have gained popularity. Herein it is suggested that word identification is based on recognition of letter stereotypical features which can be abstracted to allow for continued accurate letter recognition if the face of changes in case, position, font, colour or size and consequently allows reading of both typed and handwritten text even where a handwriting is unfamiliar (Bowers, 2000; Coltheart, 1981). Early models have also emphasised the important of letter order to enable the reader to distinguish words such as 'tale', 'late', teal' and 'leat'. Thus a variety of models such the interactive-activation model (McClelland and Rumelhart, 1981; Rumelhart and McClelland 1982), the later DRC model (Coltheart, Rastle, Perry, Langdom & Ziegler, 2001) and the MROM model (Grainger and Jacobs, 1996) have suggested encoding mechanisms based on letter slots. The word 'lick' for instance would be assigned four slots, beginning with L in the first slot and K in the last spot, represented as $C_1A_2R_3E_4$ (Harm & Seidenberg, 2004). Yet, the model fails to adequately represent perceptual similarity between words which may have no overlapping slots, such as $N_1A_2P_3$ and $S_1N_2A_3P_4$ (Davis, 2005; De Moor & Brysbaert, 2000). It also fails to explain how we are able to effortlessly make sense of scrambled test such as the example shown below from a widely distributed email message.

> *Aoccdrnig to rseearch at Cmabrigde Uinervtisy, it deosn't mttaer in waht oredr the ltteers in a wrod are, the olny iprmoetnt tihng is taht the frist and lsat ltteer be at the rghit pclae.*

In fact, jumbled primes (e.g. waht) have been shown to be equally effective in facilitating lexical decisions as non-jumbled primes (e.g. what; Forster, Davis, Schoknecht & Carter, 1987). Subsequent models have therefore argued for a focus on relative rather than absolute letter position (Schoonbaert & Grainger, 2004; Whitney & Berndt, 1999; Whitney, 2001). Distributed-connectionist theories which do not rely on the presence of individual word representations have also been put forward (Harm & Seidenberg, 2004; Plaut, 1997; Plaut & Booth, 2000). However, to date connectionist models have been unable to successfully model behavioural data of skilled readers (Coltheart et al., 2001; Granger & Jacobs, 1996) judging whether a verbal stimulus is a word or a non-word (Plaut, 1997; Plaut & Booth, 2000). Finally, McClelland and Rumelhart (1981; also see Rumelhart & McClelland, 1982) suggested an interactive-activation model, which relies on several levels of word analysis starting from feature identification to letter identification and word recognition. The model suggests a continuous feedback system incorporating both excitatory and inhibitory effects occurring simultaneously based on identified features, letters or words.

Other Factors Affecting Retention of Verbal Stimuli

In addition to the factors discussed above, several other attributes of verbal stimuli may also affect stimulus encoding and retention likelihood. These factors include verbal characteristics such as word length, word frequency, age of acquisition, orthographic neighbourhood size, concreteness and imageability, all of which have been found to significantly impact processing of verbal stimuli.

Word length has been theorised to affect verbal recall as an artefact of rehearsal time required where longer words, in particular those that take longer to pronounce, being less likely to be recalled (Cowan, Day, Saults, Keller, Johnson & Flores, 1992). The most commonly provided explanation for this effect relates to decay of information in the phonological loop (Baddeley, 1986; Baddeley, Chincotta, Stafford & Turk, 2002) although alternative explanations have been put forward arguing only a minor impact of trace decay (Neath & Nairne, 1995), the lack of a necessary correlation between pronunciation time and rehearsal time (Lewandowsky & Oberbauer, 2008) or highlighting the retention benefits of word frequency, which is often associated with word length (Cowan, Wood, Nugent & Treisman, 1997). In addition, a word length effect has also been observed to occur in picture memory, even when picture naming is not required during encoding (Hulme, Silvester, Smith & Muir, 1986), lending additional weight to the argument that an explanation based merely on pronunciation time is insufficient.

As well as word length, natural language frequency impacts recognition and recall of verbal stimuli (Oldfield & Wingfield, 1965; Roodenrys, Hulme, Lethbridge, Hinton & Nimmo, 2002). In everyday language use, there are some words which are used more frequently than others; for instance, one is substantially more likely to encounter the words ‘afternoon’ or ‘work’ in an everyday conversation than the words ‘mythical’ or ‘segregation’. Scarborough, Cortese and Scarborough (1977) found that high frequency words are identified faster than low frequency words, an effect which appears to affect both encoding and retrieval mechanisms and may be at least in part attributable to exposure recency of a stimulus. While this beneficial word frequency effect has been consistently observed in recall tests, the opposite pattern is found for recognition memory. Recognition tests have been found to benefit from both words that occur with lower frequency in everyday language as well as longer words (Schulman, 1967; Kinsbourne & George, 1974). It should be noted that the two measure tend to co-vary, but both attributes are theorised to independently add to the rarity of a word making it stand out from other more commonly encountered words. However, Underwood and Freund (1970) discovered that reduced recognition accuracy for high frequency words was observed only when previously encountered words were displayed among other high frequency stimuli but not when distractor words were of low frequency.

In addition, age of word acquisition has also been found to play a significant role in the retention of verbal stimuli (Ellis & Morrison, 1998; Brysbaert, Wijnendaele & Deyne, 2000; Juhasz, 2005). However, findings are related mostly to initial retrieval of a word rather than recall or recognition memory following a recent exposure. Gilhooly and Gilhooly (1979) found that an earlier age of acquisition of picture labels aided retrieval of labels, but age of acquisition did not affect recall or recognition of picture labels (Gilhooly & Gilhooly, 1979). The absence of the age of acquisition effect in either recall or recognition was also reported by Coltheart and

Winograd (1986). Morrison, Ellis & Quinlan (1973) argued that word frequency and age of acquisition, much like length and frequency, are closely correlated. In a controlled analysis they found that age of acquisition was a better predictor than word frequency (Morrison, Ellis & Quinlan, 1992; Morrison & Ellis, 1995). Belke, Brysbaert, Meyer and Ghyselinck (2005) obtained similar results. Their findings indicated an impact of semantic context effects being more pronounced in late-acquired words resulting in greater naming latencies. Similarly, Carroll and White (1973) found picture naming effects for age of acquisition, but not word frequency, with labels acquired earlier in life being retrieved faster, while Barry, Morrison and Ellis (1997) obtained separate effects for both word frequency and age of acquisition in naming speed of picture from the Snodgrass and Vanderwart (1980) database (also see Gerhand & Barry (1998) for effects of word frequency and age of acquisition on reading performance). Testing word recognition in different modalities, Turner, Valentine and Ellis (1998) reported that word frequency affected visual but not auditory lexical decision speed, while age of acquisition showed a significant effect for both modalities.

Furthermore, the number of a stimulus' orthographic and phonological neighbours impacts processing. Ziegler, Muneaux and Grainger (2002) found that while phonological neighbourhood size increased response latencies in an auditory lexical decision task, orthographic neighbourhood size produced a facilitatory effect. Similar effects of orthographic neighbourhood size were observed by Andrews (1997). In addition, Laxon, Masterson and Moran (1991) found that young children find words with larger orthographic neighbourhoods easier to read. Reminiscent of the already discussed effects of word frequency and orthographic distinctiveness, while a larger orthographic neighbourhood size benefits naming, a smaller orthographic neighbourhood size benefits recognition (Glanc & Greene, 2007), with the same pattern observed for phonological neighbourhood size (Roodenrys et al., 2002; Yates, Locker & Simpson, 2004).

Finally, stimulus concreteness affects recall with more concrete stimuli showing a clear memory advantage (Hamilton & Rajaram, 2001) for both recall and recognition memory (Roche, Tola & Tehan, 2011). Fliessbach, Weis, Klaver, Elger and Weber (2006) reported fMRI results showing increased bilateral activation for concrete stimuli during both encoding and recognition. Schwanenflugel, Akin and Luh (1992) have suggested that the recall benefit observed for concrete stimuli may occur as a result of the strategic use of imagery to form a mental image of the stimulus in question. Imageabililty as an independent variable, as well, has been found to positively affect recall of verbal material, although Richardson (1975) suggests that an effect of imageabililty may be restricted to abstract stimuli. Klaver, Fell, Dietl, Schür, Schaller, Elger and Fernández (2005) theorised that the enhancing effect of imageability may relate to deeper conceptual processing of more readily imagined stimuli. As with effects of word length and frequency, concreteness and imageability of a stimulus are often highly correlated. However, due to the very nature of the stimuli designed for the current work, only concrete items or those which can be pictorially represented will be eligible to the used. This stimulus design may encourage participants to make greater use of imagery techniques when encoding items.

Global and Local Processing

In both object recognition and attention allocation a distinction is made between processing of global and local features of an object. These processes have been confirmed theoretically (Navon, 1977), empirically (Navon, 1977; Martin, 1979; Navon, 1991) and biologically (Fink, Halligan, Marshall & Frith, 1996; Martinez, Moses, Frank, Buxton, Wong & Stiles, 1997). The impact of global and local dimensions was first studied by Navon (1977) in the now aptly named Navon task. This consisted of showing participants a series of large-scale single letters, which were made up of smaller letters. Hereby the small and large letters could be either the same (congruent) or different (incongruent) as shown in Figure 1.11 below.

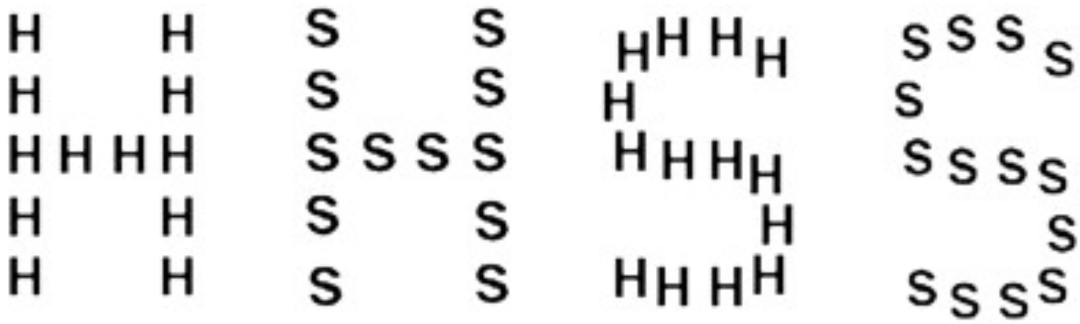

Figure 1.11: Typical stimuli used in the Navon task, from left to right: congruent, incongruent (x2), congruent.

Navon (1977) discovered that global features were reliably and consistently processed before local features and resulted in interference when a response to local features is required. Interference is increased if global and local letters are visually similar, for example more interference is observed if a large F is made up of small Es than if it is constructed of small Ms (Stirling & Coltheart, 1977). These results have since been confirmed by a large body of research (Stirling & Coltheart, 1977; Martin, 1979; Navon, 1991; Paquet, 1992; Love, Rouder, & Wisniewski, 1999) where global features have been observed to be subject to priority processing over local detail even following extensive practice of local processing (Paquet, 1992). Later findings confirmed the distinction of global and local processing mechanisms by observing distinct brain activation patterns for both actions. Fink et al. (1996) reported that while global processing led to greater activation in the right hemisphere, local processing mostly resulted in left hemispheric activation. Similar patterns were observed by other researchers. While Martinez et al. (1997) confirmed left hemispheric activation for local processing, they reported that global stimuli result in activation of both hemispheres. This is in line with findings obtained by Han, Weaver, Murray, Kang, Yund and Woods (2002) who identified overall greater spikes in activation for processing of global compared to local features. Finally, Proverbio, Minniti and Zani (1998) reported brain activation patterns indicative of greater sensory activation from global than local stimuli. In particular, they observed processing interference from global but not local distractors.

Despite the robustness of this effect further investigation by Martin (1979) revealed that increasing sparsity of local features (see Figure 1.12 below) can reverse global precedence and allow processing of local features to be prioritised. By increasing the size of local relative to global stimuli, salience of local features increases, therefore directing attention towards them before attending to global appearance. In addition it needs to be considered that when the global shape is made up of too few local features the integrity of the global object may be compromised. That is, a square made up of sixteen circles is significantly more likely to be perceived as a square than one made up of only four circles.

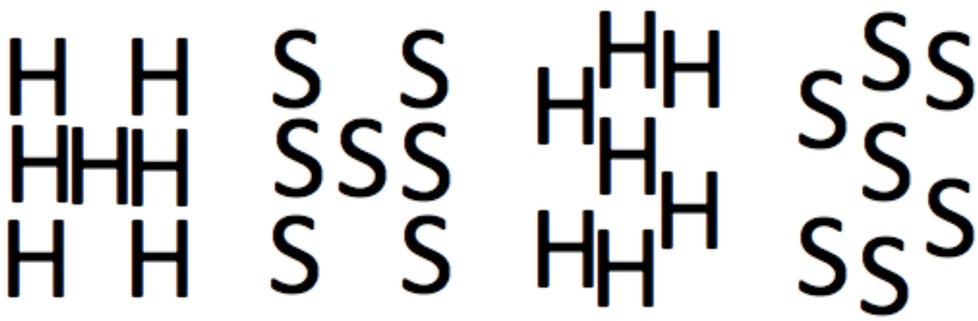

Figure 1.12: Navon task stimuli with increased sparsity.

Further evidence for the importance of salience is provided by Weinbach and Henik (2014), who directly manipulated salience of local and global features and found that interference was observed from the salient dimension regardless of whether local or global features were made salient (see Figure 1.13 for examples of stimuli).

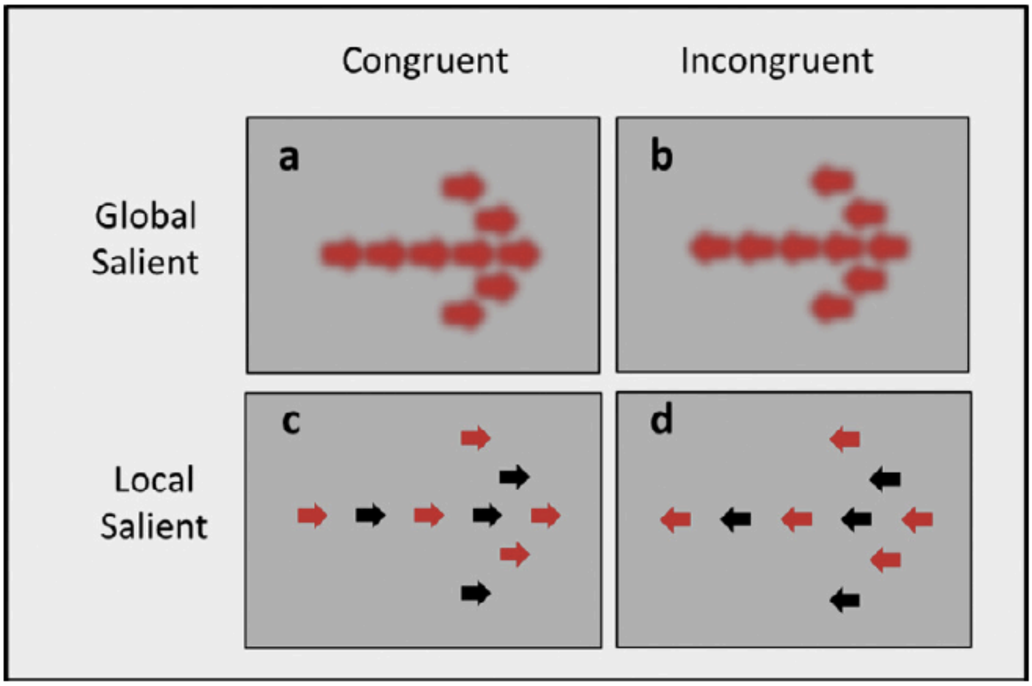

Figure 1.13: Manipulation of global and local salience from Weinbach and Henik (2014).

While the global processing precedence is robust and persists under a number of manipulations (Stirling & Coltheart, 1977; Paquet, 1992), evidence suggests that it is learnt rather than innate. Findings by Poirel, Mellet, Houdé and Pineau (2008) show that global processing priority does not emerge until around the age of 9 years, prior to which local features are processed before global ones.

However, Kimchi (1992) argues that global processing precedence refers merely to an initial priority but must not necessarily bear significant impact on a final evaluation of dimension salience or the eventual interpretation of the object as a whole. Additionally, attention can be directed at will to either global or local features when required by task demands (Miller, 1981; Kinchla, Solis-Macias & Hoffman, 1983). While Miller (1981) suggested that attention can be directed to local or global features equally quickly, Paquet and Merikle (1984) suggested that global priority processing exists, but is extremely short lived. While it is observed at 10ms following stimulus onset, attention can be successfully directed towards local features at only 40ms following stimulus onset. Kimchi (1992) further argues that to achieve holistic processing of global and local dimensions not only the separate features need to be processed but instead the interrelation between both aspects as well as between individual features on either level. Thus, the full holistic nature of an object cannot be accounted for by looking merely at its component parts in isolation. This analysis of holistic processing is highly reminiscent of the Gestalt principle of perceptual primacy of wholes (Kimchi, 1992) as well as the assertion that the whole is bigger than the sum of its parts (Wertheimer, 1938). In addition, Kimchi (1992) draws attention to the lack of real world application of global/local processing assessments such as the Navon task since letters are not commonly made up of smaller letters and stimuli lack plausibility with no relation existing between the global and local dimension. Instead she suggests the use of more naturalistic stimuli such as investigating the processing pattern of an entire face versus processing of its local features. Of course it could equally be argued that such stimuli could display a global processing bias as a result of local features not naturally occurring in isolation. In fact, Beaucousin, Cassotti, Simon, Pineau, Kostova, Houdé and Poirel (2011) argue that meaning and consistency are crucial to the perception of visual scenes and that meaningful objects, which are congruent with the context are more readily integrated into existing patterns than objects which are incompatible with their background. Weissman, Mangun and Woldorff (2002) report that more effortful processing and greater allocation of selective attention are needed to resolve conflicting distractor information, while attention directed to non-conflicting information is reduced in comparison.

But the global/local interference pattern is not observed exclusively in Navon type stimuli. Albrecht and O'Brien (1993) conducted a study into text comprehension and found that reading speed was impaired when local information (i.e. a particular action of a character) contradicted previously received global information (i.e. a general description given about a character). Thus, when participants read about Bill as a relatively weak, old man, reading speed was negatively affected when they later encountered a situation in which he ran and picked up a young boy who had fallen in the street. No such effect was observed when Bill had been previously been described as being in his thirties, fit and working out regularly. This showed that context-incompatible information takes longer to integrate into an established mental image than information compatible with a previously activated schema. Finally, Förster, Liberman and Shapira (2009) discovered that task framing encouraged either global or local processing precedence. In particular, if a task was framed as novel, global processing priority was observed whereas framing the task as familiar led to priority processing of local information. The same results were obtained from both a Navon task and a Gestalt completion task, observing local facilitation and global interference for a familiar task and global facilitation and local interference for a novel task, compared to a neutral condition where the task was not framed as either novel or familiar. On the whole, these findings confirm the global processing precedence with unfamiliar objects first being assessed on a global level before attention is directed to local features following familiarisation.

Stroop and Garner Effects

Learning is fast and almost automatic. Children can't help learning to understand and describe the world around them and it is clear that they do so whether instructed to or not. They gather and process information at an incredible rate and somehow manage to retain vast chunks of novel information very reliably. But the human capacity for information processing does not merely respond to conscious intention but successfully codes and stores information that was never intentionally memorised (Miller, 1968). A number of experimental paradigms such as the Stroop effect (Stroop, 1935), the Simon effect (Simon, 1969) and the Garner effect (Garner, 1974) investigate the impact of involuntary processing. In the Stroop task participants are required to look at a set of colour words printed in different coloured inks and asked to name the ink colour rather than read the word; a task that has been proven notoriously difficult (MacLeod, 1991). In the original Simon task (Simon & Rudell, 1967) participants are auditorily presented with the words 'right' or 'left' and required to press a right or left button in response. The difficulty arises from auditory information being randomly presented to either the right or left ear. Responses are substantially faster when trials are congruent, presenting the word 'right' to the right ear or 'left' to the left ear. The same pattern is observed when stimuli are visually presented on the screen on either the right or left side of the screen and participants are instructed to focus on the verbal content of the stimulus while ignoring physical location (Simon, 1969). Both the Stroop and Simon task could essentially be described as specific instances of Garner interference. The phenomenon occurs when two dimensions, a task-relevant and a task-irrelevant one, are varied independently and the irrelevant dimension interferes with processing of the relevant dimension (Pomerantz & Garner, 1973). A common example is judging the numerical value of numbers (e.g. picking the larger number) while simultaneous varying the relative physical size (font size) of each number. In trials where the numerically larger number is printed in larger font faster reaction times are observed than when numerical and relative physical size are incongruent (Schwarz & Ischebeck, 2003; Tzelgov, Meyer & Henik, 1992), although Panksy and Algom (1999) found that the magnitude of the Garner interference in this instance was mediated by target discriminability, that is, if numeric size could be easily determined based on number of digits, interference observed from physical size was decreased. Garner (1974) argued that while some dimensions are separable and can be processed individually without causing interference, other dimensions are of an integral nature and are therefore processed together as though they constituted a single unified dimension.

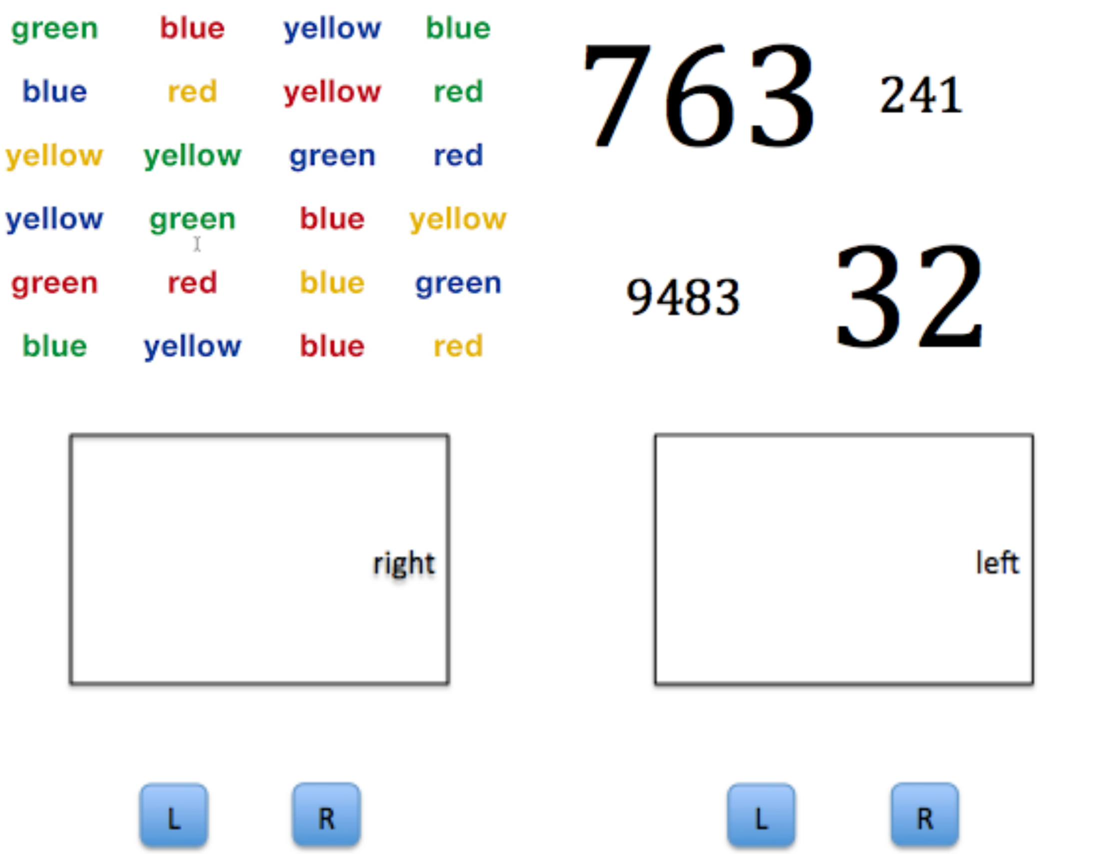

Figure 1.14: Examples of stimuli used in the Stroop (top left), Garner (top right) and Simon (bottom) effects.

Through these experiments the question of automaticity of processing has been raised. Interference arises from an irrelevant dimension leading to stimulus-response incompatibility of the required output (Durgin, 2000; De Houwer, 1998) although DeHouwer (2003) found that stimulus-stimulus compatibility as well adds to the overall effect. The problem participants need to solve is ignoring an irrelevant feature of the stimulus, which lies on the same dimension as the required task response. Thus, the stimulus-response incompatibility leads to an error in the desired response. Irrelevant information is processed involuntarily or automatically and inhibitory processes cannot interfere fast enough to prevent the undesired response. While in congruent trials facilitation is observed to an extent, this effect is usually much smaller than interference in incongruent trials, which has repeatedly been found to occur (MacLeod, 1991). Stroop interference has been investigated in many different conditions and variations. Thus it can for example be found even when only a single letter of a word is coloured (Besner & Stolz, 1999). Wide evidence has also been reported for a cross-modal Stroop effects such as responding "girl" to a male speaker and vice versa (Hanauer & Brooks, 2003). Furthermore, when looking in more detail at how information is organised in long-term memory, Rayner and Posnansky (1978) found that non-words, which sounded similar to a distractor word produced more interference than a graphemically similar stimulus. This may indicate that interference occurs on a phonological rather than conceptual level of response selection. Findings presented by Durgin (2003) further suggest that while participants are aware of the correct answer, they need additional time to select it from other activated, competing responses. In past research, semantic variations have been developed. While Altman & Davidson (2001) report that words such as "lawn" and "blood" can be strongly associated with colours and hence produce interference effects, De Houwer (1998) describes a semantic adaptation where bi-lingual speakers respond by saying either “occupation” or “animal” to a verbal stimulus based on the language it is written in; i.e. responding for example with “occupation” to a Dutch word, whereas saying “animal” upon the occurrence of an English stimulus. The stimuli used described either occupations or animals. Both facilitation and interference effects were found.

Based on the evolutionary purpose of processing dimensions such as size, shape and colour, Hasher and Zacks (1984) propose the concept of automaticity of processing. Treisman and Gelade (1980) suggest that there is indeed evidence for processing without attention or conscious awareness. Shiffrin and Schneider (1977; also Schneider & Shiffrin, 1977) on the other hand argue that automaticity should be understood as automatisation and is a result of extensive practice rather than an innate process. Indeed, research has shown that practice can significantly reduce Stroop interference, which has repeatedly been attributed to the incapability to suppress an automatic reading response to a verbal stimulus (McLeod, 1991). Similarly, van Asselen, van der Lubbe and Postma (2006) suggest that automaticity should be seen as a continuum rather than a dichotomous scale. This automatisation hypothesis has also been raised in relation to the Stroop effect. The argument suggests that reading the verbal stimuli has, by means of practice, become an automatic response and cannot be inhibited, whereas identifying the ink colour is not obligatory and not one of the affordances of processing written text. Thus, Durgin (2000) argues that the meaning of a word is the most salient aspect and will automatically be processed before attention is paid to the ink colour a word is written in. In contrast, interference from ink colour on word reading (a reverse Stroop effect) is observed only following extensive practice in naming ink colour and decays quickly when identification of ink colour is no longer task-relevant (Stroop, 1935). Finally, Virzi and Egeth (1984) suggested a translational account of the Stroop effect suggesting that the delayed response in incongruent trials arises because the relevant non-verbal information needs to be translated into a verbal response, while a conflicting verbal response is readily available. In support of this theory, Durgin (2000) reports that when a colour patch can be pointed at in response to ink colour, Stroop interference disappears. However, when a colour patch needs to be pointed out in response to the colour word rather than the ink colour, the Stroop effect re-emerges.

A Holistic Processing Approach

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Processing of Integrated Verbal and Non-Verbal Information

The use of integration of verbal and non-verbal material has been popular in everyday use for a long time. It is among the frequently employed approaches for the creation of company logos and other areas of art and design. Examples include the CAMRA (Campaign for Real Ale; est. 1971) logo, which is designed to resemble an ale mug, Ikea's Live – Play – Create campaign, where words were created to look like floor plans, or Swan Property Management, where the S is replaced by the outline of a swan, emphasising the neck to resemble the outline of the letter. These and similar examples can be seen in Figure 1.15 below.

Figure 1.15: Examples of logos using an integrated presentation format, incorporating both verbal and non-verbal aspects.

The same approach was also used by Dan Fleming, an American artist and designer, in the creation of his word animals, where he exclusively used letters to outline the shapes of a wide variety of animals as seen in Figure 1.16 below. This type of creative design is also frequently employed by primary school teachers for engaging children in the making of imaginative art projects.

Figure 1.16: Word animals designed by Dan Fleming.

Yet, despite its apparent popularity and clear use of a wide range of established phenomena in human information processing, the actual effectiveness of these types of stimuli in relation to encoding processes and capability for retention has so far remained largely unexplored (Oh & Kang, 2015). If the purpose of designing logos of this nature is to render them more memorable and recognisable (Blake, Nazarian & Castel, 2015) it is surprising that these aspects have not been explored in greater detail in a more scientific setting. In order to make a comprehensive argument for the combination of verbal and non-verbal material in an integrated design that goes beyond its aesthetic and artistic components, a more quantifiable approach is needed to assess the efficiency of this type of processing to achieve the desired effect of memorability and recognisability.

The present work aims to rectify this lack of experimental investigation into the effect on incorporating verbal and non-verbal information into a single stimulus. Based on the findings presented in this chapter, the current body of work argues that full processing cannot occur without accessing the entire concept. This should include both a verbal and non-verbal representation of the concept since both are intricately linked to form a holistic image of an object (Bloom, 2000), similar to the dual route system suggested by Paivio (1971). In addition, it is suggested that integrating the two types of information into a single visual object will further aid processing, comprehension, and recall (Treisman & Gelade, 1980). The current work will draw on findings and theories discussed in this chapter as well as additional literature to construct an argument for the benefits of holistic processing and an approach through which it may be achieved. For this purpose a set of over 100 stimuli was designed where each item represents a physical objects for which both verbal and non-verbal information is displayed in an integrated format. As in the art and design examples shown above, the letters of each word were used to form the outline and detail of each visual object. To this effect, manipulation of global shape, individual letter shape, letter distribution, font type and font colour, as well as variation of pattern were employed. The resulting stimuli, while retaining their capacity for verbal identification, also take on a strong pictorial appearance, allowing identifying information to be derived both through a verbal and a non-verbal pathway. Figure 1.17 below shows examples of the stimuli used in the experiments reported here. All stimuli were designed specifically for the current work using PowerPoint and Meritum Paint.

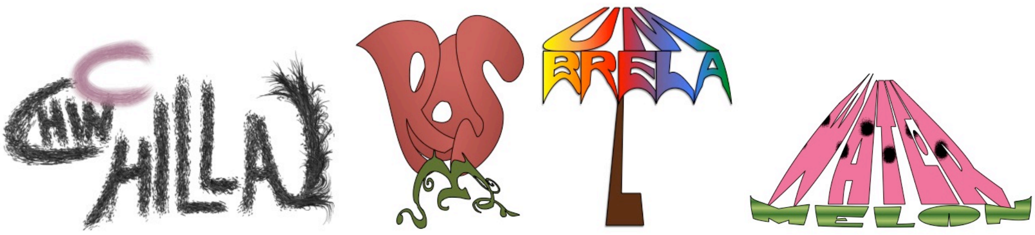

Figure 1.17: Examples of integrated stimuli used in the current study, combining verbal and non-verbal information into a single visual object.

The current section will provide a more detailed explanation of how each area discussed above relates to holistic processing and in what fashion previous results are compatible with the manipulation suggested here as well as how they relate to the predictions that can be made about the effect of processing holistic, integrated information based on existing data.

Object Recognition. The two main object recognition theories based on either a full three-dimensional mental representation or a view-dependent process of recognition based on mental rotation and comparison to familiar viewpoints both have important insights to offer. While we are arguably able to construct a three-dimensional representation of familiar objects and could probably draw both usual and unusual views of these objects from memory, some viewpoints are also clearly more iconically recognisable than others. Object recognition is achieved through a wide number of dimensions including shape, size, colour and texture. While each on their own can evoke mental images of certain objects, it is the combination of all, which conclusively determines object identity. While it is certainly possible to reliably recognise a large number of every objects from simple line drawings

(Snodgrass & Vanderwart, 1980) when shape alone is not a reliable identifier, recognition can be significantly impaired. Thus, telling apart a peach and a nectarine would not normally pose a problem, yet in the absence of textural and colour information, a discrimination based on shape along may prove almost impossible. In particular, Rossion and Pourtois (2001) suggest that colour is a strong determinant in object identification. The stimuli created for this study will primarily make use of shape, colour and spatial distribution and typical views will be used wherever possible to ensure most effective recognition through a non-verbal route. Since the newly created stimuli do not offer the potential for full realistic representation of objects, it is important to use available features to their greatest advantage to achieve maximum potential for correct object identification. Using a number of dimensions rather than individual identifying features will allow processing to be based on the conjunctive occurrence of a number of features. Looking at the first image in Figure 1.17, a number of non-verbal features co-occur to activate the relevant concept. Firstly, the overall shape resembles a chinchilla, yet this may not be immediately recognisable on its own. In addition, colour is provided to distinguish between the colour of the fur and ears and finally texture is added, visually grouping the ear, body and tail. The combination of all these cues finally add up to form a more complete image, which in combination with the verbal information serves to form a holistic representation of the concept in question.

Gestalt. This is precisely the approach suggested by Gestalt psychologists who have traditionally emphasised the importance of the whole over its parts. Neither the global shape nor the local detail on their own may be capable of evoking the mental image of a chinchilla, yet their combination succeeds where the individual parts fail. Perceptual principles of Gestalt psychology rely on identification of proximity, similarity and visual grouping all of which is essential in allowing holistic stimuli to be processed successfully. Furthermore these allow identification of salient areas relevant for object identification and recognition. While verbal and non-verbal material is clearly complementary in an ideal design (Mayer & Anderson, 1991; Chun & Plass, 1996), it has often been studied in isolation or in comparative designs investigating advantages and disadvantages of each. In contrast, the current work aims to bring the two types of information together and combines them into a single perceptual object, which allows simultaneous processing of both dimensions. Through the manipulation of individual letters in terms of font, colour, relative size, shape and spatial distribution, it allows the verbal label to be altered to concurrently represent both the verbal and non-verbal aspects of each stimulus, creating a new whole, which truly becomes larger than the sum of its parts. In this design, the verbal and non-verbal aspects do not merely co-exists or compliment each other, but form a single, united object, which incorporates both representational dimensions at once. Since the two dimensions relate meaningfully to one another processing occurs on the holistic level advocated by Gestalt psychologists. While real life physical objects are not naturally formed of the words and letters that describe them, there is a clear conceptual relationship between the two dimensions, so that full integration may be achieved.

Language. As a result of existing knowledge, prior experience and every individual's own logic and understanding, words may activate different meanings for different people, which may lead to a difference in comprehension of verbal communication. Asked to imagine a sunflower, someone may be inclined to imagine a single long-stemmed flower, a field of yellow and brown or perhaps the famous painting by Van Gogh. All of these representations are certainly accurate although their resemblance to a prototypical sunflower varies considerably. This pictural uncertainty may, however, be eliminated by providing a ready-made image of the object in question. Presenting a picture alongside the word essentially removes or at the very least reduces the need for mental reconstruction of the object in question and it is unlikely that the imagination will stray far from the provided image (see Figure 1.18).

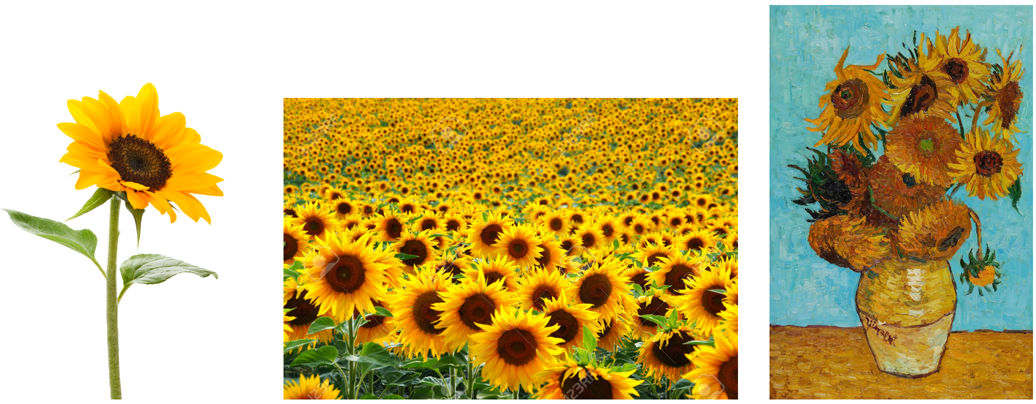

Figure 1.18: Different pictorial representations of the sunflower concept.

Thus, when the presented stimulus itself contains a simplistic but prototypical representation of a sunflower, it is likely that conceptual information will be accessed directly and the picture shown will serve to activate the concept. This could potentially reduce the effort involved in conceptual activation by eliminating the need for constructing a detailed mental representation (see Figure 1.19).

Figure 1.19: Integrated representation of the sunflower concept.

The current approach makes use of the identifying potential of language cues while striving to eliminate effortful translation to a conceptual representation through dual provision of both verbal and non-verbal information simultaneously. While language is an important determinant of concept identity and adds greatly to understanding, it is most effectively used when augmented by non-verbal information in a complimentary fashion (Mayer & Anderson, 1991; Chun & Plass, 1996).

Concepts. Conceptual processing is key to paving the way to a holistic approach to information input. Conceptual activation can occur through both a verbal and a non-verbal route since arguably both constitute an equally strong representation of the concept. While conceptual activation can occur independent of verbal naming (Brown & McNeill, 1966), language has become an integral part of human communication and associations between a concept and verbal label are as strong as knowledge held about the concept in question (Bloom, 2000; Pinker, 1994). Sevostianov, Horwitz, Nechaev, Williams, Fromm and Braun (2002) found that larger, more widespread brain activation occurs when both verbal and non-verbal information is processed simultaneously, rather than in separate conditions. This supports the benefits of holistic processing while also emphasising the potentially increased mental effort associated with it. Conceptual understanding develops from a very young age (Quinn et al., 2002; Needham et al., 2005). Concepts are formed before children develop a grasp of language. Yet, as language has evolved to be the main tool of human communication, verbal information has become deeply ingrained in conceptual representations (Pinker, 1994). As such the concept of a cat may be represented by either a picture of a cat, the word 'cat' or both. Since both dimensions independently lead to the activation of conceptually related information, it could be argued that providing both simultaneously should result in superior processing. Yet, under normal conditions, this is impossible. While both types of information are fully integrated into the conceptual representation they belong to, they must be processed separately by the visual system as they commonly occur in different visual locations. The stimuli created for this study aim to circumvent this need for separate processing and instead allow simultaneous focus on both verbal and non-verbal stimuli in a fully integrated visual design (see Figure 1.20). While integrated stimuli are not able to capture the feel, smell, sound or behaviour of a cat, they are capable of conveying the two most basic levels of identification used in human communication: verbal and visual information. It is expected that this format of presentation will lead to fuller conceptual access, deeper processing and better retention.

Figure 1.20: Pictorial, verbal and integrated representation of cat.

Levels of processing. The levels of processing hypothesis suggests that deeper access is achieved by investigating an object beyond its surface features. It is perhaps not surprising that the effect occurs primarily with the use of verbal material and is substantially less evident in picture stimuli (D'Agostino et al., 1977). In order for words to fulfil their purpose they need to be read and understood. Investigating a word's orthographic structure or determining whether it rhymes with another word when sounded out does not access its primary function of being understood as a referent. Even a set of meaningless non-words can undergo the structural and phonemic processing levels without problem since these levels do not touch the essence of the word. These lower levels could even be considered a form of preventing natural processing rather than a shallow analysis preceding access of word meaning (Richardson-Klavehn & Gardiner, 1998). While both the structural and phonetic tasks concentrate on superficial – and often irrelevant – properties of the word, it is only the semantic task that fully engages with the concept to which the word refers. Conceptual processing improves memory through full activation of the concept and its properties. Although some analysis of orthographic and phonemic surface features certainly occurs it is generally immaterial beyond aiding word identification. In contrast, where pictures are concerned, surface features are the primary identifying features they possess. Unlike orthographic patterns, pictures are interpreted by examining their surface features, their shape, colour and spatial distribution of visually distinct parts. Consequently, structural analysis of pictures is comparable to semantic analysis of words since it aids interpretation and access to meaning. Similarly, with stimuli created for the current work, structural analysis of the surface features of the words used has the potential to lead to conceptual processing as a result of the manipulation of physical surface features, which now take on an overall pictorial character. That is, structural analysis of the visual appearance of the word is likely to activate the pictorial representation of the word since letters are arranged and edited to resemble the object in question.

Dual coding. Dual coding theory suggests that processing of verbal and non-verbal information is complementary irrespective of modality (Paivio, 1971, 1986, 1991). It further argues that while language provides direct access to verbal information, pictures offer direct access to non-verbal information and result in faster activation of full conceptual and semantically related information. It further assumes that the verbal and non-verbal channels are separate and information can be processed through both channels in parallel. If this assumption of complementarity and parallelism is accurate, it stands to reason that presenting both verbal and non-verbal information pertaining to the same concept in combination will lead to faster access through both processing routes simultaneously. In addition, full visual integration ensures that both types of information are processed concurrently rather than successively without the need to switch attention between the two. The stimuli used in this work test this assumption by providing a combination of both verbal and non-verbal information incorporated into a single object, uniquely suited to concurrent processing through a dual route system. While both input formats use the same modality, that is, both are encoded through the visual channel, the verbal and non-verbal dimensions should still produce an additive effect, particularly since as a result of the integrated design attention is always directed at both dimensions at the same time. Dual coding predicts more efficient and complete processing when complimentary verbal and non-verbal information is provided side by side; an effect, which has been observed in various tests of learning from instructional material (Hibbing & Rankin-Erickson, 2003; Beacham et al., 2002; Mayer & Anderson, 1991). Consequently, novel, integrated stimuli created for this study should be uniquely suited to allow both types of information to be processed concurrently, making the best possible use of a dual route system. Therefore, integrated stimuli combining both verbal and non-verbal content should be processed faster and lead to better retention than either type of information alone.

Picture superiority. Pictures have consistently been found to result in better recall than verbal material (Shepard, 1967; Blanc-Brude & Scapin, 2007, Stenberg et al., 1995; Mitchell, 2006). In response, a multitude of experiments have been conducted with the aim to improve recall of verbal material (McDaniel & Einstein, 1986; McDaniel, Einstein et al., 1995; Riefer & LaMay, 1998, Zechmeister, 1972;

Hunt & Elliot, 1980; Hunt & Toth, 1990, Craik & Lockhart, 1972; Craik & Tulving, 1975). Previous work has often examined the differences between picture and word processing, looking at each separately to investigate, compare and contrast the two. Less work has been done on using pictures and words as corresponding facets of the same concepts and studies that do exist often look at material in an educational context (Hibbing & Rankin-Erickson, 2003; Beacham et al., 2002; Mayer & Anderson, 1991) rather than exploring the complementary potential of verbal and non-verbal material at a more basic level. Given that pictures produce superior recall, it follows that they may be beneficial in enhancing recall of verbal material. While this has been shown to be the case in text comprehension (Hibbing & Rankin-Erickson, 2003), it should also be tested in recall of individual words. The current work will aim to consider the broad amount of existing research and build on prior knowledge to enhance both processing and retention of presented material by using a combination of both words and pictorial features to enhance processing. In particular, the current body of work does not focus on learning complex material by means of acquisition and abstraction of knowledge, but instead centres its interest on recall of lists of single words. While the novel stimuli used here are not pictures in the traditional sense, they may possess enough of a pictorial character to elicit non-verbal processing and therefore allow these stimuli to benefit from superior picture processing. Since the letters of each word are used to create the pictorial character of each stimulus, information is fully integrated and the non-verbal features are tied directly to the verbal dimension. The word and picture essentially become the same object. This might result in verbal material being processed similar to a picture, substantially increasing retention likelihood.

Top down versus bottom-up processing. Due to their often singular nature, words are more commonly subject to top-down processing. Once language has been acquired the majority of words we encounter are familiar and are simply interpreted based on their representation held in long-term memory. Similarly, when an unfamiliar word is encountered, meaning needs to be derived from context and is often applied to the unfamiliar word based on top-down processes as a result of contextual interpretation, since the word's structural and phonetic properties are of little use when trying to interpret meaning. Although Maurer, Pathman and Mondloch (2006) have suggested that there exists an intuitive relationship between phonetic properties and the objects they are expected to describe, this is not a reliable method of interpreting unfamiliar verbal material.

In contrast, pictures are made up of a collection of informational levels including shape, colour, texture, spatial distribution and perceived depth, all of which have the potential to capture attention and elicit separate processing mechanisms. Consequently, pictures are more likely to be processed through a bottom-up route, allowing them to be interpreted on the basis of their physical features and salient local detail. However, pictures can also be subject to top-down processing where the identity of the picture is ambiguous or resemblance to the object the creator had intended is more tenuous, such as is the case in Figure 1.21 below.

Figure 1.21: Examples of realistic representation of a children's drawing of a car.

Stimuli used for the present work are composed of both verbal and non-verbal features, using individual letters of each word to create a basic pictorial representation. While the pictorial dimension can be seen as simplistic and slightly abstract, it relies on object identification on the basis of shape, colour, spatial distribution and texture. Many of these dimensions can potentially capture attention (Moore & Egeth, 1997; Pratt & Hommel, 2003; Ruz & Castillo, 2002) and elicit bottom-up processing and conceptual activation when the physical resemblance to a familiar object is detected. Once the connection has been made, top-down processing can then be effectively employed to interpret the verbal dimension and facilitate letter identification in the unfamiliar format. In turn, once the verbal identification is completed, physical features will be rendered even more relevant and the holistic nature of the stimulus will be reinforced.

Mental Imagery. Mental imagery improves recall by encouraging participants to actively imagine objects or situations, including visualising physical appearance. Stimuli used in the experiments presented here already include a visual representation of stimuli by manipulating individual letters to form a visual representation of the physical object, although it needs to be considered that the pictorial nature of each stimulus while reminiscent of the referent object is still of a highly abstract nature compared to a photographic representation or detailed drawing. While mental imagery has been shown to be an effective memory aid (Pressley, 1976; Craig, 1973; Hiscock & Cohen, 1973; McDermott & Roediger, 1994; Ganis et al., 2004) this effect could arise either from the mere activation of the visual representation of the object or from the act of mentally constructing it. That is mental imagery could elicit an effect comparable to seeing the actual object or a picture of it or could be a result of the effort exerted when constructing a detailed mental representation of the object based on information held in long-term memory. Of course, it is also possible that a highly abstracted image, such as the ones used in this body of work may elicit greater mental imagery by activating only the basic features of the object while failing to form a full picture. Mental imagery processes may be used to compensate for this rudimentary design to fill in additional detail from long-term memory. It is possible that presenting participants with a primitive representation of an object may engage imagery processes to allow the image to be embellished and any missing detail to be filled in.

Salience, Bizarreness and Distinctiveness. Like many of the other factors already discussed, salience, bizarreness and orthographic distinctiveness have been identified as memory enhancing factors. Salient stimuli are given processing priority in order to assess them for response requirements. Stimuli used here make substantial use of colour, which has been identified as a salient dimension (Xing, 2000). In addition, their unexpected format is likely to draw attention and incite interest for further investigation. Although an effect of bizarreness has generally been found only in conditions where bizarre stimuli are contrasted directly with common stimuli, the words created for this study are of an entirely novel nature and participants are extremely unlikely to have encountered anything similar in the past. Therefore it is possible that stimuli will still appear salient in comparison to normally encountered text and exert a significant impact on retention probability. In addition, while congruent features are not intended to be bizarre, they may appear so to participants as a result of being highly unfamiliar. In contrast, incongruent features are likely to be of a bizarre nature and may serve to compare the effect of bizarreness to conceptually orientated processing. While orthographic distinctiveness in its traditional form is expected to have very little impact in this case since altered features substantially change the orthographic pattern of the words used (McDaniel, Bahill & Bugg, 2016), stimuli certainly do have a distinctive shape and appearance.

Global and Local Processing. Findings regarding global versus local processing may also be useful in understanding processing of integrated verbal and non-verbal stimuli. In the current stimulus design letters simultaneously function as local features and form an overall global shape, which has a pictorial character. Evidence has shown that global features are processed before local features (Navon, 1977; Stirling & Coltheart, 1977; Martin, 1979; Navon, 1991). This suggests that participants should become aware of the overall shape of stimuli before identifying single letters of each word. Shape recognition should result in primary conceptual activation and ease letter identification in congruent trials. Shape identity would also be further mediated by information derived from letters, creating a coherent relationship between the local and global level. In addition, since the global features correspond to non-verbal information and the local features correspond to the verbal dimension, this suggests that non-verbal information will be processed before verbal information. According to dual coding theory (Pavio, 1971; 1986) non-verbal information is processed more quickly and activates related semantic information faster than verbal cues. Therefore tying non-verbal information to global features and verbal information to local features coincides with naturally assumed processing mechanisms and should facilitate access to holistic conceptual information. If global processing priority occurs for the current stimuli, this may also suggest that non-verbal processing may have a stronger impact on overall processing, perhaps making them more susceptible to other processing effects such as the picture superiority effect, Gestalt recognition principles and conceptual processing. It would also suggest that attention would immediately be drawn to the most unusual aspect of these words, namely their shape, potentially increasing item salience.

Stroop effect. The large body of evidence also highlights the importance on conceptual processing in the Stroop effect. While participants understand the task requirements and are aware of the response they need to give, a delay is often observed in response selection and occasional errors do occur. Thus, although participants correctly access and process the non-verbal stimulus, interference is observed from an irrelevant verbal stimulus as a result of the conceptual relationship between the two colour words, which are closely adjacent in the semantic lexicon. In addition, more processing time is required to retrieve a verbal label for a visually presented colour than to simply read out a colour word. Evidence has shown that the presence of a closely semantically related concept can inhibit retrieval of a verbal label (Lupker, 1979; Costa et al., 2005).

Stroop and Garner effects are unique in that they use stimuli where verbal and non-verbal information is fully integrated and assess how processing of one dimensions impacts processing of the other. Yet, although Stroop and Garner interference have been discussed for more than eighty years, the focus has predominantly been on how it hinders processing. Investigation has consistently focused on how the cognitive system works to resolve conflict and overcome contradiction. While it is true that facilitating effects have generally been small, this should not automatically mean that they do not deserve further scrutiny. Stroop and Garner stimuli have the potential to offer unique insight into processing of integrated dimensions and the effects of congruence on combining information in this format. Yet, interest in this area has been sorely lacking. The current study endeavours to embark on this new perspective on the interplay of verbal and non-verbal information and the so far untapped potential it may hold. It is argued that meaningfully integrating verbal and non-verbal material may yield advantages for both processing efficiency as well as information retention.

CHAPTER 2

Dual Processing Revisited

Abstract

Paivio's (1971) Dual Coding Theory states that information can be processed through both a verbal and a non-verbal route. While verbal processing is considered slow and effortful, non-verbal processing allows faster activation of the semantic network and is subject to a high level of automaticity (Paivio, 1971). The current chapter investigates dual coding theory and in particular aims to test it under conditions where verbal and non-verbal information is integrated into a single stimulus. While providing dual access to information via both a verbal and non-verbal route has in the past been shown to improve understanding and recall (Paivio & Csapo, 1973; Stenberg, Radeborg & Hedman, 1995), it stands to reason that integrating the two pathways into a single stimulus will further increase this effect (van Leeuwen & Lachmann, 2004). In two experiments, a series of integrated stimuli containing both verbal and non-verbal information were created and tested in comparison to pictures, pictures with verbal labels, and words only. In Experiment 1, which used a distractor categorisation task, significant main effects for presentation format were found for both reaction times and recall scores. Integrated items were processed most slowly, while separated stimuli were recalled most accurately. No effects of picture superiority or impact of exposure time on recall were observed. Experiment 2 omitted the categorisation task, leading to the detection of both picture superiority and an effect of exposure time. Significant main effects were observed for presentation format on both processing time and recall. A significant main effect was also found for native language. Integrated stimuli were once more recognised most slowly, but native speakers recognised items significantly more quickly than non-native speakers. Picture only stimuli produced the best recall scores in Experiment 2. While no processing or recall benefit was observed for integrated stimuli, the data did reveal a

different processing pattern for these items. In the absence of a prescribed encoding strategy, integrated stimuli most closely resembled picture processing. These findings suggest that featural integration has an important role to play in information processing and merits further investigation.

Introduction

The discovery that pictures and words are processed differently has long been established. Picture naming has reliably been shown to take longer than naming verbal counterparts (Carr, McCauley, Sperber & Parmelee, 1982). This effect has been argued to arise from the fact that while words have direct access to lexical information, picture naming involves the active retrieval of verbal information, minutely delaying the naming response (Theios & Amrhein, 1989). However, when the required response task is altered so a decision must be made on a semantic or conceptual level, such as completing a categorisation task, pictures reliably lead to increased performance compared to words (Friedman & Bourne, 1976). It has accordingly been suggested that while pictures open up the possibility of fast access to semantic information and somewhat delayed access to verbal labels, the reverse is true of words (Smith & Magee, 1980).

Dual Coding Theory

Dual coding theory was first discussed almost half a century ago when Paivio (1971) suggested that external stimuli could be processed via a dual route system. At its core, dual coding theory suggests that information can be processed and encoded in two different ways; via a verbal pathway as well as by using a non-verbal route. Paivio did not merely suggest a different processing practice, but theorised that the two pathways would be qualitatively different. The theory states that information encoded via the verbal route is more effortful to process and consequently takes longer, whereas the non-verbal pathway is faster, operates on a more automatic level and leads to faster spread of information and activation through the semantic network.

Information can be processed via either or both of these routes, where use of both routes generally leads to deeper encoding and a better chance of retention. While some stimuli are more suited to single pathway processing, others more readily allow for fast and easy access via dual route access. Thus, words would be naturally processed through the verbal channel, while pictures would be more readily processed through a non-verbal route. However, the retrieval of a verbal label is a deeply ingrained process in picture encoding (La Heij, 1988), thus offering up the potential for the stimulus to be processed via a dual coding route, resulting in superior memory performance for picture targets.

When tested in a levels of processing approach (Craik & Lockhart, 1972) it became clear that while words behave in accordance with the expected pattern, pictures show no difference in recall scores between the phonemic and semantic encoding conditions (D'Agostino, O'Neill, & Paivio, 1977). This strongly suggests that pictures are subject to processing mechanisms that differ substantially from word processing. This could be evidence for an already superior processing strategy for picture stimuli, which is activated regardless of task instruction. In terms of dual coding theory, this means that the phonemic task requires retrieval of the verbal label in addition to non-verbal processing occurring automatically, therefore immediately resulting in both encoding pathways being triggered.

Pictures have further been found to outperform words on a recall task when encoding was undertaken under conditions of auditory distraction, a combination of both auditory and visual distraction was more detrimental for recalling pictures than words, with words showing no further negative effect. Visual distraction alone did not noticeably affect either type of stimulus (Pellegrino, Siegel & Dhawan, 1975). This supports the assumption that words are indeed encoded verbally, while pictures make use of both verbal and non-verbal systems. Disrupting one channel will not result in a significant reduction of performance, but disrupting both processing channels leads to decreased recall performance for picture targets, presumably due to interference in both available encoding routes.

Dual coding has also been tested in a repetition-lag paradigm (e.g. Glenberg, 1976; Thios & D'Agostino, 1976) where it has generally been found that repeating a stimulus with few or no intervening items in between does not produce an additive effect to increase recall likelihood. That is, presenting a target word twice or more in quick succession will not result in a more reliable memory trace. Only when sufficient lag is included between presentations, can a benefit be derived. This was tested for both words and pictures (Paivio, 1991; Paivio & Csapo, 1973), yielding identical results. However, when a target was presented first as a word and then as a picture or vice versa, additive effects were observed even at 0-lag, suggesting strongly that verbal and non-verbal cues are processed qualitatively differently. Although repetition of verbal labels can also have an additive effect for bilinguals when the target stimulus is presented both in their first language (L1) and their second language (L2), performance is significantly better for verbal/non-verbal pairs than verbal/verbal pairs (Paivio & Desrochers, 1980).

Dual coding theory does not however apply only to individual targets. Education research has shown that visual information will generally lead to superior learning as well as conceptual retention, compared to verbal instructions alone, particularly when supported by complementary auditory or verbal information (Moreno & Mayer, 2002; Carney & Levin, 2002).

Recall through Imagery

Interestingly, recall performance can be manipulated by altering the encoding strategy through experimental instruction. If participants are asked to imagine words, ease of recall is significantly increased and recall accuracy will be double to merely naming words, bringing verbal targets on par with naming pictures (Paivio, 1991, Paivio & Csapo, 1973). Paivio and Csapo (1973) also noted that imagery-based encoding strategies yield a greater level of performance improvement than the addition of verbal encoding strategies. Kieras (1978) suggests that the effectiveness of imagery may be brought about by the incidental encoding of irrelevant information, which can later offer supplementary cues and open additional routes to retrieval. In an experiment reported by Durso and Johnson (1980), participants were instructed to process either words or pictures via three different mechanisms: focussing on verbal aspects (label, spelling), aspects of the image (drawing time, image quality) or conceptual features of the actual object (functionality, frequency of use, etc). The study reported that while words produced superior recall when encoding focussed on aspects of the associated object, pictures resulted in superior recall when encoded verbally. No difference was observed between the two presentation formats for trials where a conceptual encoding strategy was employed, although in this condition participants were more likely to falsely report having seen an image of the object even when they had been shown a word. Similar patterns emerged for both recognition and recall tasks. The results suggest that while words derive additional benefit from non-verbal encoding directions, pictures become more memorable as a result of added verbal processing. As such, the results implicitly support the theory that while words are encoded verbally by default, pictures are subject to non-verbal encoded unless otherwise directed. These findings also support the importance of dual coding, showing a clearly superior pattern for stimuli encoded through activation of both verbal and non-verbal pathways over those encoded through a single route only.

Picture Superiority

Dual coding theory was developed in part to help explain what has been termed the picture superiority effect. Research has repeatedly and reliably shown that recall of pictures is superior to recall of verbal stimuli when no encoding strategies are given (e.g. Paivio & Csapo, 1973; Stenberg, Radeborg & Hedman, 1995). When tested to extreme levels, it was found that participants were capable of accurately recognising in excess of 2000 pictures, even three days after initial exposure (Standing, Conezio & Haber, 1970). The picture superiority effect persists throughout the lifespan although there is disagreement regarding its relative strength at different ages (Whitehouse, Maybery & Durkin, 2006; Maisto & Queen, 1992). Whitehouse et al. (2006) suggest an increase with age while Maisto and Queen (1992) noted a general decline in memory performance, but still reported a significant memory advantage for pictures over words. The picture superiority effect has also been found to be intact in Alzheimer's patients and individuals with mild cognitive impairment adding to the overall robustness and validity of the effect (Ally, Gold & Budson, 2009). It has furthermore been observed in associative memory tasks with associated pairs of pictures being recognised significantly more accurately than associated word pairs (Hockley, 2008).

It is not unreasonable to assume that from an evolutionary perspective it would be greatly beneficial for picture processing to significantly outperform verbal processing. While the word 'tiger' may not induce a particularly large defensive response, a realistic, life-sized drawing of a tiger, particularly if encountered under uncertain circumstances may well prompt you to take a few steps in the opposite direction. This ties in neatly with dual coding theory in that the non-verbal route, which is preferred to picture processing, can elicit a substantially faster response as a result of faster processing and faster activation within the information network (Paivio, 1971). It is not surprising then, that using PET scan technology, research has confirmed that pictures and words are processed in different areas of the brain (Grady, McIntosh, Rajah & Craik, 1998).

The majority of researchers agree that the picture superiority effect is most likely brought about by underlying conceptual processing, with perceptual factors also playing a minor role (Stenberg, 2006; Pezdek, Maki, Valencia-Laver, Whetstone, Stoeckert & Dougherty, 1988). Weldon and Coyote (1996) have however argued that the effect may arise from visual distinctiveness rather than conceptual memory processes. In support of conceptual processing, Stenberg, Radeborg and Hedman (1995) reported that in a recognition task picture to word priming is significantly greater than word to picture priming, suggesting that richer information is encoded for pictorial than verbal stimuli. Yet richness of information is unlikely to be a sole deciding factor and picture complexity has not been identified as a determining factor in the picture superiority effect (Nelson, Metzler & Reed, 1974). Pezdek et al. (1988) found that when participants were shown simple and more complex pictures of objects and asked to recognise them, they were more likely to identify simple pictures as having been previously seen than more complex images of the same object, strongly suggesting a process of mental abstraction taking place during the encoding process. This effect was further strengthened when schematic encoding was encouraged by appropriate instructions during the experiment. The researchers concluded that while distinguishing pictures of previously seen or unseen targets posed little problems, accurately recalling the level of detail contained in a picture resulted in significantly greater difficulty. Gentner and Loftus (1979) also add that picture recall can be influenced by imposing a verbal label during encoding, such as describing a character as either walking or running, which may later lead to reports of having seen a picture congruous to the label even if this was not the case. This phenomenon is also widely supported by studies investigating the accuracy and reliability of eyewitness testimony (Loftus, 1975; Loftus & Zanni, 1975).

While it has certainly been shown that pictures are processed differently from verbal stimuli, they still remain subject to the same restrictions of human information processing. Thus, reducing the available time to process targets by showing images at a rate too fast to allow full encoding, will eliminate the picture superiority effect (Paivio, 1991) and as with verbal material, picture memory is increased by an increase in exposure time and extended inter-stimulus presentation intervals (Tversky & Sherman, 1975). Both pictures and words have also been shown to be sensitive to the same experimental manipulations such as frequency effects, interference and facilitation effects (Kroll & Potter, 1984). In addition, while a PET study found that different brain regions are activated during superficial processing tasks such as reading or naming of words or pictures, very similar activation patterns are observed for performing the same semantic tasks on either words or pictures (Bright, Moss & Tyler, 2004), suggesting that the same semantic links serve to complete both procedures.

Lastly, the picture superiority effect is not eliminated in incidental memory, but persists as it does in intentional learning. In fact, performance for incidentally learnt pictures has been found to be equal to intentionally encoded verbal stimuli, but significantly exceeds recall of incidentally encoded words (Noldy, Stelmack & Campbell, 1990; Cohen, 1973). Picture stimuli have also been reported to be less vulnerable to the reduction of rehearsal time following even a very brief exposure (Cohen, 1973).

The Effect of Congruence

For information to be meaningfully combined, congruence between dimensions plays an integral role (Garner, 1976). The effect of congruence, or the lack thereof, is most clearly exhibited in the Stroop task (Stroop, 1935). In its traditional version, it requires participants to identify the ink colour of a colour word, which typically does not coincide with the colour of the writing, thus resulting in a lack of congruence between the desired response and irrelevant distractor. It has been suggested that the difficultly experienced by participants performing this task results from a combination of early interference between features, early target selection, and late response competition (Rueckl, Suzuki & Yeh, 1991; Sanders & Lamers, 2002). It has been reliably observed that when the distractor and target are congruent (i.e. 'blue' written in blue) performance is improved, while incongruence (i.e. 'blue" written in green) leads to a decrease in performance, respective to neutral trials where only a single dimension is presented or the distractor is entirely irrelevant to the task, i.e. using neither colour nor colour-associated words (Ménard-Buteau & Cavanagh, 1984). The same pattern of effects has been observed in a large body of experiments investigating the Stroop task and its variations (MacLeod, 1991) and persists if picture naming is required with an incongruent word superimposed upon the image (Lupker, 1979). Findings by van Leeuwen and Lachmann (2004) suggest that the more similar the distractor is to the target, the more easily it can become integrated with the target and the greater the level of observed interference will be. In other words, high similarity distractors are harder to suppress due to automatic conceptual integration (Kramer & Jacobson, 1991).

Congruence effects persist even if the congruence between dimensions is merely perceived and of an entirely more arbitrary nature. Maurer, Pathman and Mondloch (2006) discovered that participants showed a distinct pattern in naming random shapes, where round shapes were more likely to be given a name containing rounded sounds (i.e. bouba) while edged shapes were more likely to be assigned a sharper sounding name (i.e. kiki). In addition, participants are faster to name sound-congruent compared with sound-incongruent objects even if they had been previously trained to use the opposite label (Kovic, Plunkett & Westermann, 2010). It should be noted that while interference can be substantially reduced by training, separation and alterations in visual grouping, facilitation effects remain robust and are largely unaffected by these factors.

Feature Integration

Another aspect, which has not been sufficiently explored in relation to verbal and non-verbal processing routes, is the effect of feature integration (Treisman & Gelade, 1980). While ample comparisons have been drawn between pictures and words and some research has been conducted into providing both types of stimuli simultaneously under both complementary and competitive conditions (Paivio & Csapo, 1973; Stenberg et al., 1995), there seems to be very little research assessing how pictorial and verbal information can be meaningfully integrated and how this will affect processing and subsequent recall (Garner, 1976). While feature integration can be achieved with both congruent and incongruent dimensions, integration of congruent features has commonly been found to be easier to process as a result of the meaningful link between dimensions (Garner, 1976). When assessing separate stimuli combined into a single object, the simple coexistence of features does not guarantee their integration (Prinzmetal, 1995), although certain dimensions such as common colouring can be used to encourage this process (Prinzmetal, 1981). First and foremost, however, the potential for a meaningful integration of the information is of high importance for successful processing (Garner, 1976). Once features are meaningfully integrated, this can aid visual search and a greater number of conjoined features can assist in excluding irrelevant objects from further processing (Wolfe, Cave & Franzel, 1989). While it has previously been suggested that each feature must be processed individually, thus adding to the overall processing load (Treisman & Gelade, 1980; Thompson & Massaro, 1989), this view has since been contradicted by other researchers (Wolf et al., 1989; Tsal, 1989) who suggest that it is a fully integrated combination of features rather than a mere accumulation that guides feature integration. In fact, a number of studies have suggested that once visual integration is achieved, all dimensions are processed in parallel (Banks, Bodinger & Illige, 1974; Banks & Prinzmetal, 1976; Duncan, 1984). This is supported by Gajewski and Brockmole (2006) who showed that an object possessing a series of integrated features is recalled as a whole, rather than a set of separate characteristics.

While the impact of distractors on target selection is well evidenced (Zajano, Hoyceanyls & Quellette, 1981; Morein-Zamir, Henik & Spitzer-Davidson, 2002), research has also highlighted the role of proximity of distractors and integration of features into a single visual object. Gatti and Egeth (1978) demonstrated that the impact of distractors is reduced significantly with increased distance from the to be attended target. Perceptual grouping of distractors alongside a target is a deciding factor in observing interference effects (Fox, 1998). If distractors and targets are not grouped into the same visual object by means of proximity, common colouring or global distribution, interference effects are substantially diminished or even eliminated (Kramer & Jacobson, 1991). While the effect of interference between dimensions is much more pronounced than any benefits derived as a result of facilitation (MacLeod, 1998) this effect is particularly strong for integrated compared to separated dimensions, especially when both the distractor and the required response need to be processed through the same channel (Flowers & Stoup, 1977). When participants are given extensive training to learn to suppress the irrelevant information and only focus on the intended target in a traditional Stroop task, an initial rapid improvement in performance over the first few days is observed in integrated stimuli before levelling out to more gradual improvement. In contrast, separated stimuli show no initial fast decrease in interference, but rather a slow improvement throughout (MacLeod, 1998). This suggests that both the integration of features and the late response competition between target and distractor are responsible for the amount of interference that is observed. When integration of features is present, additional processing effort needs to be exerted to separate the relevant from the irrelevant information, resulting in greater difficulty when performing the task.

A Language Phenomenon

Another important aspect to consider for studies dependent upon the use of language related phenomena is the question of whether differences may arise between native and non-native speakers. Substantial research has been conducted in bilingual speakers of varying grades of proficiency as to whether language processing occurs separately for each acquired language and functions through lexical mapping or is instead mediated via a common conceptual database. The majority of this research suggests that all languages spoken by an individual are mapped directly onto the same concepts, while lexical pairing only plays a minor role (Potter, So, Von Eckardt & Feldman, 1984; Dufour & Kroll, 1995; Kroll & Stewart, 1994; Pearson, Fernandez & Oller, 1993). Thus, Potter et al. (1984) observed that naming pictures in a second language (L2) produced faster reaction times than translating from the primary (L1) to the secondary language, even if the speakers were not fully fluent in L2. In addition, Kroll and Stewart (1994) found that lexical information is retrieved through a conceptual route for both picture naming and translation tasks. In fact, bilingual children as young as six years of age show clear evidence of conceptual mapping across both languages (Gonzalez, 1994) and they develop proficiency in both languages at the same rate at which monolingual children acquire a single language further suggesting that the same system underlies acquisition of both L1 and L2 (Pearson et al., 1993). However, a study by Kroll and Sholl (1992) suggested that during initial second language learning in adults, lexical mapping strategies may play a more prominent role in language production before becoming more conceptually orientated with increasing levels of proficiency.

Despite this close conceptual link between L1 and L2, Scarborough, Gerard and Cortese (1984) have concluded that proficient bilinguals are perfectly capable of performing language specific tasks and are able to ignore distractor items from their other language at will, although other findings suggest that some level of activation of the to be ignored language may occur regardless of task demands (Colomé & Miozzo, 2010).

Interesting dynamics can be observed when investigating the Stroop effect in bilinguals of varying L2 proficiency levels. When first acquiring language as a child, words are associated with objects and concepts and this relationship is continuously reinforced and strengthened throughout the life-span (da Costa Pinto, 1991). While similar processes are at play when a second language is acquired, word associations in L2 may never grow to the same level as in L1. Exploring the emotional Stroop task in bilingual speakers, Havelka and Eilola (2010) found that while native and non-native speakers showed the same behavioural reaction when reading negative or taboo words in L1 or L2, greater levels of physical arousal were observed when negative or taboo terms were viewed in L1 than L2. This suggests that different processes may be involved in language processing of bilinguals and monolinguals. A common finding indicates that bilinguals in particular show less interference in Stroop tasks than monolingual speakers (Esposito, Baker-Ward & Mueller, 2013; Marian, Blumenfeld, Mizrahi, Kania & Cordes, 2013). Esposito et al. (2013) argued that this may occur due to greater practice in inhibiting competing responses from different languages. In support of this theory Bialystok (2009) reported a bilingual advantage in controlling cognitive processes. However, it should be noted that other studies have failed to produce superior performance in bilinguals (Okuniewska, 2007) or even found worse results for bilinguals compared to monolingual participants (Rosselli, Ardila, Santisi, Arecco, Salvatierra & Conde, 2002).

Nevertheless, greater interference is commonly observed in L1 compared to L2 (Mägiste, 1984) in line with the aforementioned greater strength of association in the native language. For participants who were mainly monolinguals with only basic knowledge of other languages, greatest interference was observed from distractors in their own language. Interference from foreign language distractors was reduced with decreasing familiarity with foreign language colour words (Dyer, 1971). Although bilingual participants showed interference from both L1 and L2 distractors, a greater effect was observed when the distractor and required response were in the same language (Dyer, 1971). While it has been found that higher language proficiency generally results in more strongly impaired Stroop performance (Singh & Mishra, 2013; Rosselli et al., 2002) interference can be observed from irrelevant L2 colour words even at low L2 proficiency levels and even if naming ink colour is required in

L1 (Sisson, 1968). Additionally, it has been observed that the particular languages spoken play an important role in the level of interference that will occur in interlingual Stroop tasks. Thus, languages showing a higher level of similarity also result in greater cross-language Stroop interference than those of a more dissimilar nature (Brauer, 1998; Fang, Tzeng & Alva, 1981). Furthermore, Miller and Kroll (2002) report that in a Stroop type translation task interference was observed from conceptually related distractors in the target language while distractors related by form (e.g. word stem, rhyme) produced facilitation. Distractors presented in the input language showed only marginal effects in either direction. This suggests that the main difficulty of overcoming the Stroop effect occurs at the stage of response selection rather than source processing.

Based on these findings it could thus be expected that encouraging conceptual processing would be beneficial to native and non-native speakers alike, although a greater gain is likely to be observed in native speakers whose conceptual associations are bound to be stronger than those of speakers having acquired a second language later in life (da Costa Pinto, 1991).

The Present Experiments

Dual processing has been examined in a number of studies (Paivio, 1991; Paivio & Csapo, 1973), showing that stimuli suited to both verbal and non-verbal information processing such as pictures reliably produce faster access to semantic activation, resulting in both faster access and higher recall accuracy. Equally, the effect of feature integration has been well established (Treisman & Gelade, 1980; Wolfe et al., 1989), demonstrating that integrated dimensions are processed in unison and features are more readily combined during information processing. If the combination of verbal and non-verbal processing via a dual route system lies at the bottom of the picture processing advantage, providing verbal and non-verbal information side by side should lead to even greater processing efficiency than pictures alone. Additionally, integrating verbal and non-verbal dimensions into a single object should further advantage processing, leading to even faster recognition and improved retention. Nevertheless, the effect of feature integration on dual processing has so far received little attention. If allowing stimuli to be processed via both a verbal and non-verbal route simultaneously increases memory performance, it stands to reason that integrating the two dimensions into a single object could hold the potential to further enhance both processing and recall. To test this theory, a Stroop-like paradigm was applied, creating a set of stimuli where semantic meaning and physical appearance were designed to correspond to each other. Interactive effects in the Stroop effect have previously been observed with ambient noise (Hartley & Adams, 1974), sleep deprivation (Sagaspe, Sanchez-Ortuno, Charles, Taillard, Valtat, Bioulac & Philip, 2006) and list manipulation of congruency proportion (Hutchison, 2011), as well as anxiety for an emotional Stroop task (Dresler, Mériau, Heekeren & Van der Meer, 2009). The current chapter therefore aimed to investigate the effect on stimulus processing speed and retention when words were given a pictorial character in accordance with their meaning, such as writing the word 'lampshade' in the shape of a lampshade, thereby focusing on facilitation through congruence rather than inhibition from an irrelevant distractor. A series of stimuli was created which contained both verbal and non-verbal information in a single integrated stimulus. This effect was achieved by creating an overall global shape reflecting the semantic meaning of each stimulus by means of manipulating font, letter colouring, letter distribution, letter orientation and individual letter shape. In order to assess the full effect of these novel integrated items, they were compared to verbal information (words only condition), non-verbal information (pictures only condition) as well as verbal and non-verbal in a non-integrated format, where pictures were shown alongside their corresponding verbal labels (separated condition).

If dual processing relies on both verbal and non-verbal information being processed through parallel channels as has been previously suggested (Paivio, 1971), items in the word only condition should be outperformed by all other types of stimuli. If the effect is a result of direct processing of both verbal and non-verbal information, it stands to reason that providing both types of information, as in the integrated and separated conditions, should produce better performance than pictures alone, since the need to effortfully retrieve verbal information would be eliminated. Furthermore, if dual processing benefits from feature integration, integrated stimuli should also display faster reaction times and superior recall over separated items. If, however, the dual processing advantage is a product of non-verbal information processing only, stimuli in the picture only condition should outperform both integrated and separated items, as the verbal information would add to the overall processing load.

Two experiments were designed with varying task instructions to investigate the combined effect of dual processing and feature integration. While Experiment 1 included a categorisation task, this was omitted in Experiment 2, to reduce any interference effects as a result of task demands. Method and findings for both experiments are described below.

Experiment 1

Incidental recall following a categorisation task was tested in four independent conditions where verbal and non-verbal dimensions were presented both together and individually with the combined dimensions being shown in both integrated and separated format. In the words only condition, only verbal labels were presented for each target while in the picture only condition a photograph of each target was presented, with any background removed from the image. The separated condition used the same images as in the picture only condition, but verbal labels were also shown underneath each image. In addition to these more common formats, a novel, integrated format was created for the purpose of the research. These stimuli were designed to combine both verbal and non-verbal information into a single item by using the letters of each word to create a global shape reflecting stimulus meaning. This was achieved by manipulating the shape, distribution, orientation, font and colour of individual letters of each word to form a shape representing the meaning of the word. This included the word 'candle', written in the shape of a candle, and the word 'broom', written in the shape of a broom. In essence, Experiment 1 will examine the effect of integration in incidental encoding of verbal and non-verbal information in comparison to non-integrated and exclusively presented pictures and words.

Based on previous findings it was expected that pictures will be both recalled more accurately than words (Shepard, 1967; Blanc-Brude & Scapin, 2007) and categorised faster than words (Glaser & Glaser, 1989). In addition, stimuli suited to dual coding were expected to outperform verbal stimuli on both processing speed and item recall (Paivio, 1971). If integrated stimuli were successful in meaningfully integrating verbal and non-verbal dimensions into a single item (Garner, 1976) and integration as a result enabled stimuli to be processed more effectively through a dual route system, they should yield a recall and processing speed advantage over separated items. If integrated items allowed words to be processed in a picture like manner, recall for integrated stimuli should be as efficient as picture recall (Shepard, 1967) even at a simplistic level of concept representation (Nelson et al., 1974). The impact of native language was also examined as previous findings suggest that native speakers are likely to derive a greater level of benefit from both dual processing and feature integration (da Costa Pinto, 1991). As a result of life-long practice and continuous strengthening between an object and its verbal label, native speakers are likely to make a faster connection between the verbal information and non-verbal cues, resulting in more efficient mental integration of information and therefore more effective conceptual activation. This would be expressed in both faster reaction times and higher recall scores for native compared to non-native speakers.

Methodology

Participants. A total of 80 undergraduate students participated on a voluntary basis. Approximately half of respondents were male (41; 51.2%). Ages ranged from 17 to 44 with a mean age of 24 years (SD=5.78 years). Just under half of the sample identified themselves as native English speakers (45%) while the remaining students spoke English as a second language. The majority of the sample was Asian (46.3%), followed by Black (22.5%), White (17.5%), Chinese (7.5%) and mixed (2.5%) with the remaining 3.8% listing other ethnic origins.

Design. Presentation format was investigated in an independent design. Participants were randomly assigned to one of four conditions: words only, pictures only, separated (pictures presented alongside verbal labels) and integrated. Twenty participants were assigned to each group. Native language was also assessed between participants, distinguishing between native and non-native speakers. Reaction times and the number of correctly recalled items were recorded.

Apparatus. The experiment was presented on Superlab version 4.0.7b running on eMacs (PowerMac6,4) with PowerPC G4 processors (1.25GHz) using OS X. Stimuli were displayed on 17" flat screen monitors at a resolution of 1280x960px.

Stimuli. The same targets were used in each condition displayed either in verbal form, as a picture, using both a picture and word label or in integrated format where the letters were altered to resemble the target object. A total of 24 items were used as targets in this experiment. Each target described a concrete object, which was easily associated with a physical representation (e.g. candle). In three of the four conditions, participants were shown either a series of pictures of the items, the words describing those same items or a picture of the target alongside its verbal label. Finally, in the integrated condition a novel representation of the object was used where the letters of the word were shaped to resemble the physical object (e.g. writing ‘candle’ in the shape of a candle). This effect was achieved by manipulating global shape, letter position and orientation and colour effects. The picture used in the picture only and separated conditions were taken from the Bank of Standardised Stimuli (BOSS, Brodeur, Dionne-Dostie, Montreuil & Lepage, 2010).

Figure 2.1: Stimuli used (from left to right) for integrated, picture only, separated and word only conditions.

Procedure. Participants provided demographic data and consent in writing before starting the experiment. They then completed the experiment individually on a computer. The experiment was run in two phases. During the presentation phase, participants were shown a total of 24 stimuli, which were displayed in the centre of the screen in different formats, depending on the condition participants were assigned to. To enable later test of incidental recall and reduce the likelihood of participants being aware of the subsequent recall test, a distractor task was administered. This consisted of instructions to classify each object as either natural or manmade and press either the ‘n’ or ‘m’ key, respectively. After having completed the task, a surprise recall test was given, asking participants to recall as many of the items as possible.

Results

All data were entered into two 4x2 independent measures ANOVAs to explore the effect of presentation format and native language on reaction times and recall scores. Descriptive statistics displaying means and standard deviations for both dependent variables can be seen in Table 2.1 below.

Table 2.1: Means and standard deviations of reaction times and recall scores for native and non-native speakers across presentation formats.

		reaction times		recall scores	
		mean	**SD**	**mean**	**SD**
integrated	native speakers	3268.74	1377.48	6.3	3.02
	non-native speakers	4328.49	1823.65	5.7	3.09
separated	native speakers	1387.23	328.87	8.6	2.41
	non-native speakers	1522.8	388.48	7.8	2.94
pictures only	native speakers	2125.49	1182.54	6.14	2.12
	non-native speakers	1701.14	699.97	6.38	2.87
words only	native speakers	1824.67	425.44	8.89	1.9
	non-native speakers	2396.03	1480.88	7.18	2.99

Reaction times. A significant main effect of presentation format was found for reaction times, $F(3, 72)=21.149$, $p<0.001$, $\eta_p^2=0.468$. Although no significant main effect was observed for native speaker, $F(1, 72)=2.224$, $p=0.14$, $\eta_p^2=0.03$, contrasts revealed that native speakers were significantly faster in recognising integrated stimuli than non-native speakers, $F(1, 72)=5.695$, $p=0.02$, $\eta_p^2=0.073$. No significant interaction was found for presentation format and native speaker, F(3, 72)=1.922, p=0.132, η_p^2=0.075. Simple effects were run using a Tukey post-hoc test. They revealed that integrated stimuli were recognised significantly more slowly than all other types of stimuli, p<0.001 for all.

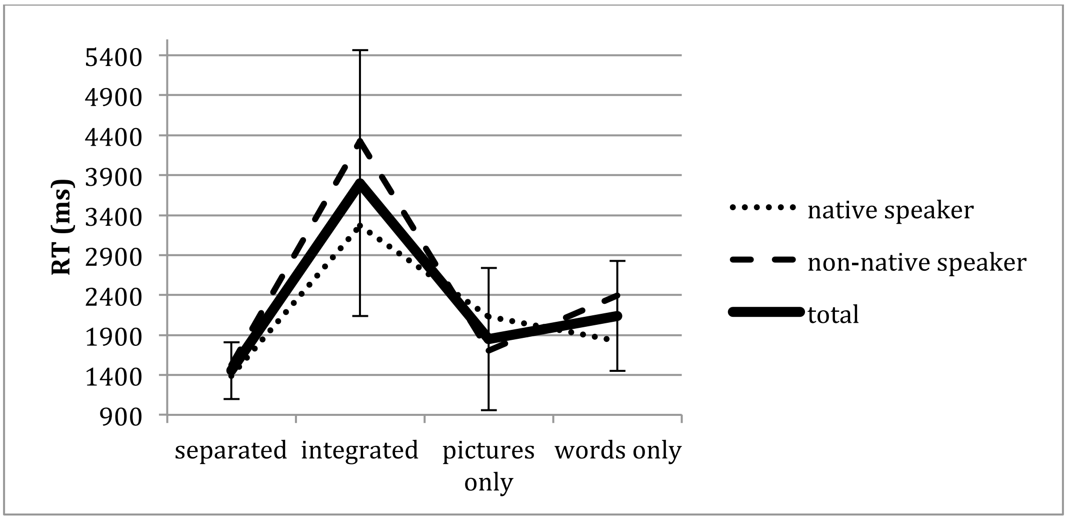

Figure 2.2: Means and standard deviations of reaction times for native and non-native speakers for all types of stimuli.

Recall scores. A significant main effect of presentation format was found for recall scores, F(3, 72)=3.463, p=0.021, η_p^2=0.126. No significant effect was found for native speaker, F(1, 72)=1.326, p=0.253, η_p^2=0.018. No interaction was found between presentation format and native speaker, F(3, 72)<1, p=0.751, η_p^2=0.017. A Tukey post-hoc test revealed only a marginal difference between integrated and separated stimuli, p=0.063, with separated items yielding higher recall scores.

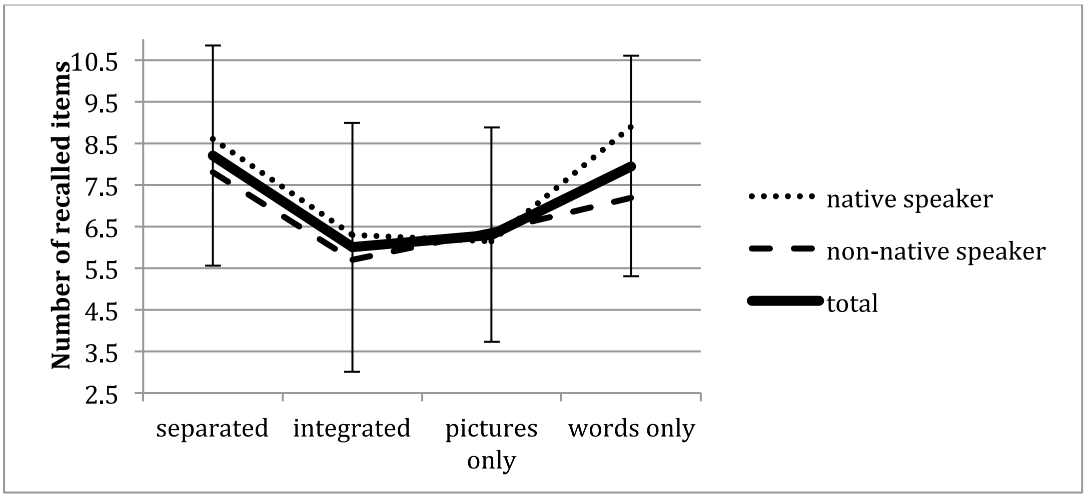

Figure 2.3: Means and standard deviations of recall Scores for native and non-native speakers for all types of stimuli.

Effect of Exposure Time. Due to the significant differences in exposure time between the conditions, which resulted in substantially longer exposure to integrated stimuli, it was decided to run correlational analyses to investigate the impact of exposure time on recall. This analysis will help to consider the likelihood of an attentional explanation of results (McDaniel & Einstein, 1986). No significant correlations emerged between exposure time and recall scores in any of the conditions.

Table 2.2: Correlations between reaction times and recall scores for the four presentation formats.

Condition	**r**	**p**
integrated	-0.06	0.801
separated	0.065	0.787
pictures only	-0.324	0.164
words only	-0.069	0.773

Discussion

The current experiment investigated the impact of feature integration in dual processing under incidental encoding conditions. Verbal and non-verbal information was presented both individually and together, in both separated and integrated format. The novel presentation format designed for the current study allowed both verbal and non-verbal information to be presented in a single stimulus. Reaction times were recorded and incidental recall was measured. It was expected that feature integration would benefit dual route processing for both reading speed and recall. No such effect was found in the current experiment. In addition, the expected processing and recall advantages for pictures over words were not observed and contrary to expectation, categorisation speed did not differ between pictures and words. It is possible that the independent design of the study diluted this effect and that any categorisation speed differences may be more pronounced in a mixed list design (Cox & Wollen, 1981). Moreover, response latencies were unusually long, which could further cloud possible differences in processing.

Some support was found for dual coding in that separated items, which presented both verbal and non-verbal information in a readily accessible format, showed improved recall over all other types of stimuli. This may suggest that dual coding in a categorisation task may happen most effectively when both verbal and non-verbal dimensions are presented separately and are highly accessible. It may therefore be possible that dual coding processes may not benefit from integration of dimensions, potentially suggesting that each channel is processed individually and information needs to be separated into the relevant channel before it can be meaningfully understood. While Durso and Johnson (1980) have shown that information can be encoded through either channel at will when instructions are provided, Paivio (1971, 1986, 1991) theorised that each type of information is uniquely suited to only one channel. This may explain why more time may be needed to allocate information to each processing channel in the absence of a prescribed encoding strategy. These findings stand in stark contrast to the findings of Banks and Prinzmetal (1976) who suggested that integration of information has a noted effect on combined processing, although their design was build on incorporating irrelevant rather than relevant information into their target stimuli. Alternatively, the increased processing time may have been a product of task requirements. Pictures are reportedly better suited to categorisation than words (Blanc-Brude & Scapin, 2007; Seifert, 1997). Having to choose and separate the most relevant dimension for categorisation from the integrated stimuli may have increased processing demands and therefore resulted in slower reaction times (Treisman & Gelade, 1980; Thompson & Massaro, 1989).

While previous research has suggested that congruency between the verbal and non-verbal dimensions could be expected to decrease processing time (Stroop, 1935), the lack of a benefit in processing time for integrated stimuli may be rooted in the lack of familiarity with the new format and associated increased cognitive load (Maisto & Queen, 1992; Ahlén, Hills, Hanif, Rubino & Barton, 2014). This confounding effect may be reduced if participants were previously given practice to get used to the novel stimuli and allowed to become more accustomed to the integrated dimensions (Ahlén et al., 2014). Faster categorisation times of integrated items for native speakers suggest that native speakers could process these stimuli more efficiently than non-native speakers. This is likely to occur as a result of more strongly formed associations between the word and the associated concept (da Costa Pinto, 1991).

While the unusual form of these stimuli may hinder reading time, their unique character along with the additive effect of both verbal and pictorial information (Paivio, 1991; Paivio & Csapo, 1973) should increase distinctiveness of the stimuli and subsequently memorability (Merry, 1980). This, however, could not be presently confirmed. Recall data for integrated stimuli obtained in this experiment suggest that they are not processed differently from either words or pictures separately and recall does not differ for these items. It should, however, be considered, that a number of well-established effects were not observed in the current data set and results therefore need to be regarded with caution. In particular, the lack of a recall benefit for pictures over words as well as equal categorisation speeds for verbal and non-verbal items is notable, as these effects have been commonly observed in previous research (Stenberg, Radeborg & Hedman, 1995 and Seifert, 1997, respectively). In addition no correlation between exposure time and recall was found, a relationship, which has been widely evidenced in earlier studies (Loftus & Kallman, 1979; Potter, 1976; Potter & Levy, 1969; Tversky & Sherman, 1975), although notably these studies have been conducted in intentional rather than incidental recall designs. Much less appears to be known about the impact of exposure time in incidental encoding, where it is regarded mostly as a confounding variable (Reynolds & Pezdek, 1992), although Woodward, Bjork and Jongeward (1973) have found that under conditions where retention requirements are uncertain for a given stimulus the effect of exposure time is eliminated.

A further aspect potentially playing a role is the influence of how an expected versus an unexpected recall test impacts memory performance. Previous research has found that in most cases, intentional learners will outperform incidental learners on subsequent memory tests (Rüsseler, Hennighausen, Münte & Rösler, 2003; Noldy, Stelmack & Campbell, 1990). While studies have shown that the same brain activation pattern has been observed to underlie both types of memory, additional brain areas have been implicated in incidental recall (Rugg, Fletcher, Frith, Frackowiak & Dolan, 1997), perhaps suggesting that more complex processes may be at work. Additionally, while intentional learning results in superior recall, it has been found that if the memory test is altered from recall to recognition, incidental learning is more effective and result in greater accuracy (Eagle & Leiter, 1964; Dornbush & Winnick, 1967). This might suggest that tests on incidentally encoded material challenge the person to distinguish a particular set of incidentally encoded information from a larger pool and select relevant items from a substantially larger potential set of memory traces. It is furthermore possible, that the results obtained for integrated stimuli may have been affected by the nature of the distraction task as pictures are more suited to effective categorisation than words and participants may have been more focused on the non-verbal rather than verbal aspects of each target. The second experiment presented here will therefore investigate these items in an amended design, eliminating the potentially confounding effects of unnecessary task instructions and instead allowing stimuli to be intuitively processed without guiding encoding strategy.

Experiment 2

Experiment 1 did not yield the expected results. While data supported aspects of dual coding, the findings were indicative of more effortful processing for integrated stimuli, which conflicts with previous research findings (Wolfe et al., 1989; Tsal, 1989). Evidence for the previously well-established picture superiority effect (Stenberg et al., 1995) was also absent, along with any benefit for integrated stimuli, which have a distinct pictorial character. Since amended features are congruent with word meaning throughout, facilitation effects of a nature similar to the Stroop effect should occur, where ink colour that matches the distractor colour word is reliably named faster and with greater accuracy than for non-matching distractor colour words (Stroop, 1935). Stroop effects have been shown to occur consistently under a wide variety of conditions (see MacLeod, 1991 for a review). These range from simple colour naming effects (Stroop, 1935) to interference observed from shapes (Hentschel, 1973; Irwin, 1978), categories (Ehri, 1976; Golinkoff & Rosinski, 1976), languages (de Houwer, 1998), auditory information such as pitch (Spapé & Hommel, 2008) or gender of the speaker (Green & Barber, 1981). Although this demonstrates considerable robustness in the occurrence of interference and facilitation in Stroop tasks, the effect might nevertheless be vulnerable to interference from task demands and findings may be altered as a result (Noldy et al., 1990). In Experiment 1, participants were required to provide a categorisation for each target, classifying it as either natural or manmade. Experiment 2 was designed to investigate the effect of integration in dual processing in the absence of potential task interference. To follow up the results obtained in Experiment 1, Experiment 2 focused attention more closely on the verbal rather than pictorial dimension of integrated stimuli, allowing them to be processed naturally in the absence of a prescribed encoding strategy. The same stimuli were used, divided between the same conditions as in Experiment 1, but task instructions were altered, asking participants to simply read words or look at pictures without requiring categorisation of the target. This is expected to eliminate any potentially confounding effects of the distractor task (Noldy et al., 1990). While participants were still not informed about the subsequent recall test, it is likely that at least some would have anticipated a recall test under the new conditions due to the simplicity of the task and their previous experience with participation in psychological experiments.

It is expected that in this study a more typical pattern of results will emerge (Paivio & Csapo, 1973; Stenberg et al., 1995), producing higher recall scores for pictures over words. The study is also expected to reveal further detail about the processing routes involved in processing integrated stimuli. If integration of verbal and non-verbal dimensions is successful in the absence of encoding instructions, the stimuli will be processed as single items, rather than being separated into two conceptually distinct objects. It is also expected that as a result of the new instructions, processing time for words will be significantly faster than all other stimuli. Based on processing times observed in Experiment 1, it is expected that integrated stimuli will produce significantly longer reaction times than other presentation formats. As in Experiment 1, the effect of native language was investigated to examine the impact of language proficiency on performance, where greater proficiency was expected to increase both recognition speed and retention of integrated stimuli.

Methodology

Participants. A total of 120 undergraduate students participated either in exchange for course credits or on a voluntary basis. The sample was predominantly female (95; 79.2%). One person did not disclose their gender. Ages ranged from 18 to 50 with a mean age of 20.72 years (SD=4.12 years). Four participants did not disclose their age. Just over half of the sample identified themselves as native English speakers (57.5%) while the remaining students spoke English as a second language. The majority of the sample was White (61.7%), followed by Black (15%), Asian (10%), Chinese (10%) and mixed (1.7%) with the remaining 1.7% listing other ethnic origins.

Design & Materials. The design was the same as in Experiment 1, with thirty participants assigned to each of the four conditions. The variables, conditions, apparatus and stimuli used were identical to Experiment 1.

Procedure. Participants provided demographic data and consent in writing before starting the experiment. They then completed the experiment individually on a computer. The experiment was run in two phases. During the presentation phase, participants were shown a total of 24 stimuli, which were displayed in the centre of the screen in different formats, depending on the condition participants were assigned to. Unlike Experiment 1, no categorisation of stimuli was required. For this experiment, participants were asked to simply press a button as soon as they recognised the displayed word or picture without performing any additional task.

Results

Data for one participant were omitted from the final analysis, as their reaction times were more than two standard deviations away from the sample mean. The remaining data were entered into two independent 4x2 ANOVAs to explore the effect of presentation format and native language on reaction times and recall scores. Descriptive statistics displaying means and standard deviations for both dependent variables can be seen in Table 2.3 below.

Table 2.3: Means and standard deviations of reaction times and recall scores for native and non-native speakers across presentation formats.

		reaction times		recall scores	
		mean	**SD**	**mean**	**SD**
integrated	native speakers	3089.67	832.91	10	4.46
	non-native speakers	4883.68	2231.31	8.23	2.62
separated	native speakers	1782.27	902.33	8.33	3.06
	non-native speakers	1965.64	814.61	9.07	2.71
pictures only	native speakers	2942.7	1366.75	12.37	3.68
	non-native speakers	4044.09	2693.75	11.27	3.82
words only	native speakers	2612.55	2225.54	9.32	3.94
	non-native speakers	2422.76	2543.58	6.7	3.2

Reaction times. A significant main effect was found for presentation format, $F(3, 110)=8.377$, $p<0.001$, $\eta_p^2=0.186$. A significant main effect was also found for native speaker, $F(1, 110)=4.685$, $p=0.033$, $\eta_p^2=0.041$. No significant interaction was found between presentation format and native speaker, $F(3, 110)=1.795$, $p=0.152$, η_p^2

=0.047. Contrasts revealed that once again, native speakers recognised integrated items faster than non-native speakers, F(1, 110)=7.373, p=0.008, η_p^2=0.063. Using a Tukey post-hoc test, simple effects revealed that integrated stimuli were recognised significantly more slowly than separated stimuli, p<0.001, and words, p=0.023, while pictures showed only a marginal difference falling just short of significance, p=0.09.

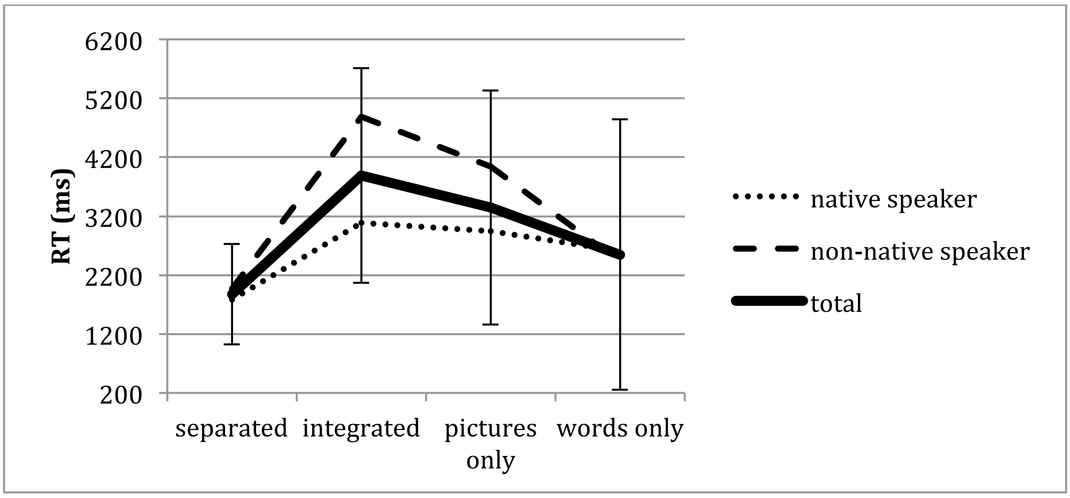

Figure 2.4: Means and standard deviations of reaction times for native and non-native speakers for all types of stimuli.

Recall scores. A significant main effect of presentation format was found for recall scores, F(3, 110)=6.151, p=0.001, η_p^2=0.144. A marginal effect was found for native language, falling short of statistical significance, F(1, 110)=3.164, p=0.078, η_p^2 =0.028. No significant interaction was found between presentation format and native speaker, F(3, 110)=1.156, p=0.33, η_p^2=0.031. Contrasts revealed a marginal effect for native speakers showing better recall of words than non-native speakers, bordering closely on a significant result, F(1, 110)=3.58, p=0.061, η_p^2=0.032. Simple effects obtained from a Tukey post-hoc test revealed that pictures were recalled better than words, p=0.001, separated stimuli, p=0.003, and integrated stimuli, p=0.018.

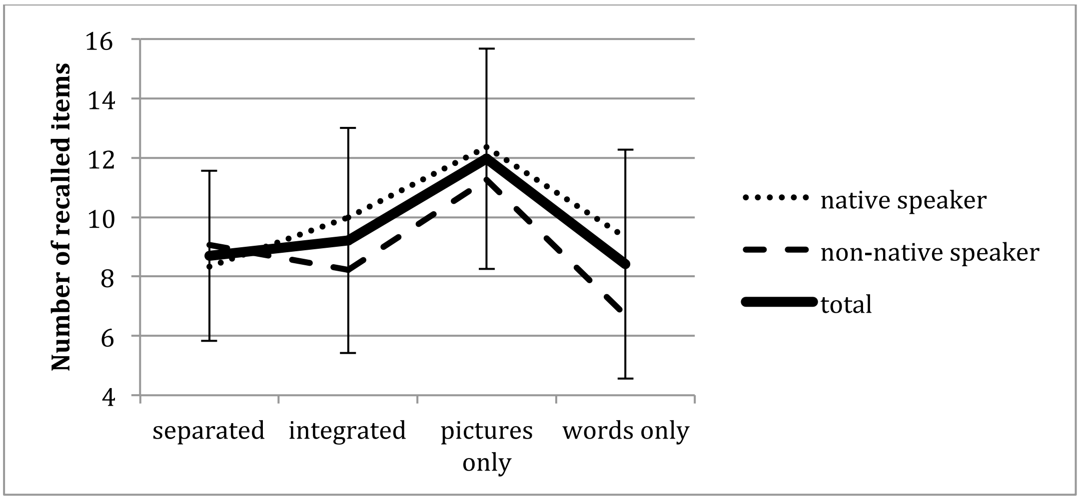

Figure 2.5: Means and standard deviations for fecall scores for native and non-native speakers for all types of stimuli.

Effect of Exposure Time. As in Experiment 1, due to the significant differences in exposure and unusually long response latencies, correlations were run to investigate the impact of exposure time on recall. Significant correlations were found for all but the integrated condition.

Table 2.4: Correlations between reaction times and recall scores for the four types of stimuli.

Condition	**r**	**p**
integrated	-0.045	0.819
separated	0.43	0.018
pictures only	0.565	0.001
words only	0.73	0.001

Discussion

Experiment 2 aimed to re-examine the effect of feature integration in dual processing in the absence of specific task demands. The same stimuli were used as in Experiment 1, but the previously administered categorisation task was omitted. It was expected that any interference of task demands would be eliminated and more typical

Stroop results would be observed (Flowers & Stoup, 1977; MacLeod, 1991). In line with expectations, better recall performance was observed for read only instructions, where it was likely that participants anticipated a subsequent recall test since no specific instructions were given and participants at university level are likely to have previously participated in or at least be aware of experiments of a similar nature and objective. In addition, the expected recall advantage for pictures over words was now observed and recall in the picture only condition was higher than in any of the other condition, which is in line with previous findings (Shepard, 1967). It should be noted that the least difference in recall scores was observed between pictures and integrated stimuli in this instance, suggesting that processing for integrated stimuli most closely resembled picture only processing, with greater processing differences observed between pictures only and the same pictures presented alongside their verbal labels in a visually separated design. This was further supported by a lack of difference in reaction times observed between integrated stimuli and pictures (although the difference approached significance, suggesting a trend of faster processing for pictures alone), while integrated items took longer to process than both words and separated stimuli. As in Experiment 1, native speakers showed faster reaction times for integrated stimuli than non-native speakers. They also demonstrated marginally better recall for words than non-native speakers. The result bordered on significance despite a very small effect size and would likely become significant in a design controlling for language proficiency. Nevertheless, a clear trend is emerging in relation to the role of native language. This suggests more effective use of integrated presentation of verbal and non-verbal information for native speakers (da Costa Pinto, 1991).

As in Experiment 1, separated items produced the fastest reaction times, although following the omission of the categorisation task in Experiment 2 they did not differ significantly from words. This effect may have been observed because separated items contain the lowest level of uncertainty regarding the intended target item. While integrated items contained the same basic information consisting of the word itself and a pictorial representation of the concept, the presentation format was unusual and clearly unfamiliar to the participants, which may have resulted in greater effort having to be exerted to successfully process these stimuli (Ahlén et al., 2014). While separated stimuli yielded the fastest processing times, pictures alone outperformed separated stimuli in recall accuracy. These findings contradict the results from Experiment 1, suggesting that overtly presented verbal information may hinder rather than help processing where no task instructions are provided and retention requirements are uncertain. Conversely, integrated stimuli displayed a tendency toward higher recall scores than separated stimuli (albeit not significantly so) for native speakers, indicating that integration has an important role to play in information processing as previously theorised (Treisman & Gelade, 1980) and demonstrated (Wolfe et al., 1989; Tsal, 1989).

As expected, pictures were now processed substantially more slowly than in the categorisation task (Friedman & Bourne, 1976). No change in processing time was observed for integrated items as a result of altering task instructions. Reaction times for separated stimuli and words were also mostly unaffected. This may suggest that these types of stimuli are subject to more robust processing patterns, showing less vulnerability to experimental manipulation. Alternatively, it is possible that different processing routes for verbal material take similar amounts of time, while picture processing is more fluent and may differ not only in the processing pattern, but also the type of information accessed. This supports the theory that while conceptual activation is largely automatic (Norris, Cutler, McQueen & Butterfield, 2006), retrieval of a verbal label is not (Brown & McNeill, 1966). Recall scores improved for all stimuli as a result of altering the instructions, but changes were most noticeable in integrated stimuli and pictures.

Previously anticipated correlations between exposure time and recall scores were now observed for pictures, words and separated stimuli, but not for integrated items. Yet recall scores for integrated stimuli did not differ from words and separated items. This strongly suggests that a different encoding mechanism was used to process these items, which is not dependent on exposure duration. The findings support the idea that the combination of feature integration and dual coding processes was successful in enhancing memorability for these stimuli in the absence of a prescribed encoding strategy.

Both reaction times and recall scores obtained in Experiment 2 suggest that integrated stimuli were processed in a manner similar to pictures in a read/view only task, suggesting that under these conditions, feature integration was achieved successfully. Under such conditions, integrated non-verbal information appears to have been successful in generating a small trend towards improved recall and allowed the contained verbal information to be processed in a manner similar to pictures, which have repeatedly been shown to be subject to superior recall over verbal targets (Stenberg et al., 1995). However, although the processing pattern observed for integrated stimuli most closely resembled picture stimuli the evidence is by no means conclusive. Since no significant recall difference was observed between integrated and world only stimuli, it is plausible that integrated items were encoded primarily through a verbal route with pictorial features playing only a small supporting role. Nevertheless, reaction time data from Experiment 2 supports a primarily non-verbal over a primarily verbal processing pattern.

General Discussion

The present study aimed to investigate the effect of feature integration in dual processing. If verbal and non-verbal information could be readily integrated into and consequently extracted from a single stimulus, it stands to reason that processing should be more efficient, significantly improving recognition speed and retention (Treisman & Gelade, 1980; Paivio, 1971). Two experiments were conducted to test this hypothesis. Experiment 1 used a classification task to test reaction times and incidental recall, while Experiment 2 used read only instructions, thus eliminating potential confounding effects of the distractor task (Friedman & Bourne, 1976; Blanc-Brude & Scapin, 2007; Seifert, 1997). While the results obtained in these experiments mirror previous findings regarding superior recall for pictures over words (Maisto & Queen, 1992; Ally et al., 2009; Shepard, 1967), no recall benefit was observed for integrated stimuli, although this had been expected based on previous research findings (Treisman & Gelade, 1980; Gajewski & Brockmole, 2006). These results are surprising as feature integration has repeatedly been shown to positively affect holistic processing (Gajewski & Brockmole, 2006; Wolfe et al., 1989; Tsal, 1989). Likewise, providing both verbal and non-verbal information side by side would be expected to aide dual processing by simultaneously activating both channels. Since integrated stimuli were designed to possess picture-like qualities it would not have been unreasonable to assume that they, too, may benefit from a picture superiority effect. The lack of an observed effect may lie in the very nature of the stimuli used. First and foremost, the novel format in which stimuli were presented would have been entirely unfamiliar to participants and may have posed a hindrance even for highly accomplished readers (Ahlén et al., 2014). While comparable designs have been used in advertising or company logo creation, it is unlikely that participants would ever have encountered more than a single item of a similar nature or made a conscious effort to process them in a limited amount of time. Thus they may have encountered some initial difficulty in making sense of the information and using the material to its fullest potential. Results from studies concerned with language processing have repeatedly suggested that letters and words may be processed in a distinct perceptual manner, unlike other visual objects (Lachmann, 2002; Zegarra-Moran & Geiger, 1993). It has also been shown that letters, unlike shapes or three dimensional objects, are encoded in an orientation-specific format (van Leeuwen & Lachmann, 2004) which means that altering letter shape, order and orientation may have led to a potential source of interference when processing the verbal dimension of integrated stimuli. Furthermore, Hogeboom and van Leeuwen (1997) suggest that when viewing visual displays of higher complexity, feature integration mechanisms and global symmetry analysis may be suppressed. This may have played a role in why integrated items failed to produce a recall advantage. Furthermore, the level of complexity was not controlled in the current experiments, although it differed substantially between stimuli. It is therefore possible that while integration was achieved for simpler items, more complex targets could not be fully integrated and therefore complete processing of the target as a single item was not achieved. This argument is, however, weakened as separated stimuli also failed to outperform items in the picture only condition. This, in turn, could suggest that dual processing arises from extracting both verbal and non-verbal information directly from pictures, rather than processing both dimensions simultaneously. It might also be possible that what has been described as a product of dual processing is in fact the result of single processing via a non-verbal route, where verbal information either has very little impact or is only retrieved much later during the encoding process. It should further be considered that presenting verbal information directly could potentially add to the processing load (Treisman & Gelade, 1980; Thompson & Massaro, 1989), thus impacting response times and encoding efficiency.

Perhaps the most startling observation was that in Experiment 2 the well-established link between exposure time and recall (Loftus & Kallman, 1979; Potter, 1976; Potter & Levy, 1969; Tversky & Sherman, 1975) was not observed for integrated items, although it was present for all other types of stimuli. This strongly suggests that in spite of obvious differences in recall scores, integrated items were processed differently from individual verbal and non-verbal dimensions as well as separated stimuli containing both types of information in a non-integrated design. Although integrated items benefitted from substantially longer exposure times, these did not lead to an increase in recall scores. Furthermore, individual item recall was not associated with exposure duration for integrated targets, although this effect was seen for all other types of stimuli. This also suggests that feature integration did impact upon item encoding. While integrated items did not show increased recall, the number of recalled items were equal to words only and separated items. Since exposure time was excluded as a factor affecting recall in the integrated condition, it follows that a different encoding mechanism was used to achieve recall scores equalling recall for other types of stimuli. Similar findings have been obtained for location recall accuracy of salient stimuli within a visual display, with eye fixation period unable to account for higher recall scores (Fine & Minnery, 2009). The exact nature of this effect, however, remains to be explored in more detail. In this context it should be noted that reaction times were longer than would have been expected. Response times for simple words in the current study were in the range of 2000ms while word reading times usually range between 300 and 400ms (Just, Carpenter &

Woolley, 1982). Participants in this experiment were unaware that their response time was recorded, which may have been at the root of the unusually long reaction times. As a result, although response time show clear differences between conditions, any conclusions drawn on the basis the data need to be treated with caution as response latencies are unlikely to be informative.

Integration has commonly been identified as a factor easing cognitive processing in congruent trials (Stroop, 1935) and it is surprising that no stronger effect was detected under the current conditions. This may be due to a lack of familiarity of the stimuli (Ahlén et al., 2014). Previous findings have suggested that in cases of feature integration the entire integrated object is retained in memory, rather than a set of separate dimensions (Gajewski & Brockmole, 2006). This may mean that if one of the dimensions is more effortful to process, it is also likely to affect processing of the other dimension. Furthermore, it may lead to confusion if participants find one of the dimensions considerably easier to process than the other and could potentially prevent recall of an integrated object if both dimensions are not processed with equal efficiency. Introducing an additional practice phase prior to testing to allow participants to become more accustomed to the new format is likely to reduce this effect (Ahlén et al., 2014). It would also allow participants to take more time to catch on to how stimuli are created and how the verbal and non-verbal dimensions relate to one another. A number of participants spontaneously reported that once they understood how stimuli were created, they found items easier to process in future trials. The likelihood of this moment of realisation occurring sooner rather than later might also be significantly affected by the individual's learning style. Integrated stimuli used in this study have a strong pictorial character and therefore might be more easily accessed by visual rather than verbal learners (Riding &

Douglas, 1993; Mayer & Massa, 2003). Cognitive learning style was not assessed in the current study, but should be considered in future research. On a number of occasions participants also stated that they could remember the shape and appearance of an item, but not the verbal content, a possible indication of the memorable potential of integrated stimuli.

The impact of native language needs to be considered as an important factor. Due to the linguistic nature of the task, language proficiency is likely to play a significant role in processing integrated stimuli. Native speakers are better equipped to interpret and use the integrated dimensions as a dual representation of the same concept than participants who have acquired English as their second language (da Costa Pinto, 1991). This advantage arises mostly from stronger links between verbal and non-verbal information pertaining to the same object, strengthened by lifetime conditioning and reinforcement of this conceptual connection. Repeatedly encountering an object alongside its verbal label will increase the connection with every encounter and these encounters are expected to be considerably more frequent for native compared to non-native speakers. The observed differences between native and non-native speakers are in line with the assumption that an abstract conceptual representation of the stimuli was achieved in the integrated condition and that native speakers were significantly more accomplished at using both the verbal and non-verbal dimensions to create a meaningful, holistic single object, incorporating both types of information.

When comparing results from Experiment 1 with findings obtained in Experiment 2, it becomes clear that simplifying task instructions had a substantial impact on outcomes in the current experiments and it therefore stands to reason that simplifying stimuli further may yield a more comprehensible understanding of the effect of feature integration in dual processing. As this level of integration is a very novel and unexplored technique, it would be beneficial to examine its effect at a more basic level, in particular in a design that allows for easy access to information without resulting in excessive interference or processing demands resulting from a lack of familiarity with the stimuli or excessive stimulus complexity (Hogeboom & van Leeuwen, 1997). This can be achieved by using more basic shapes that are more readily recognisable, therefore limiting potential targets and keeping the confounding impact of readability and ambiguity to a minimum.

In summary, the present chapter investigated the effect of feature integration in dual processing by combining verbal and non-verbal information pertaining to the same concept into a single object. The impact of integration was examined both after administration of a categorisation task and under read/view only instructions. Experiment 1, which included a distractor categorisation task to ensure incidental encoding, yielded unreliable results, failing to produce an effect of superior picture recall as well as a link between exposure time and recall likelihood, although both effects have been well established in the literature (Hockley, 2008; Maisto & Queen, 1992 and Reynolds & Pezdek, 1992, respectively). Experiment 2, where the categorisation task was omitted, produced results supporting both picture superiority as well as an effect of exposure time on recall for all but integrated stimuli. This suggests that integrated items were indeed processed differently from all other types of stimuli. For recall accuracy, integrated items showed a processing pattern most similar to pictures. Data further revealed that integration of verbal and non-verbal information may be more readily processed by native speakers than foreign language users.

The findings show that while the exploration of integration clearly has merit, more extensive research is needed to understand exactly how it affects information processing. Chapter 3 will take a more basic approach using only simple features instead of the more complex graphic designs employed in the current chapter.

CHAPTER 3

Integration and Segregation in a Shape Stroop Paradigm

Abstract

Findings from Chapter 2 indicated that integration of verbal and non-verbal information could be achieved successfully and processing mechanisms could be altered as a result. Results from Experiment 2 suggested that simplifying task instructions yielded results in line with established effects. Consequently, stimuli were simplified in the current experiments. Stroop effects (Stroop, 1935) have been observed with a variety of manipulations, including font colour, category membership and geometric shape. Both the effect of congruence and level of integration have been previously explored but less focus has been placed on the interaction between the two or the impact of local versus global features of the target. The current chapter investigates the effect of integration and segregation of congruent and incongruent stimuli in a shape variant of the Stroop task, using geometrical outlines rather than colours as target and distractor. Attentional control settings were altered and participants were instructed to attend to either the shape word or the shape itself under conditions of both integration (Experiment 4) and segregation (Experiment 3) of verbal and non-verbal information. Significant main effects on reaction times were found for integration and congruency as well as an interaction for control setting and congruency. Significant main effects on correct responses were found for congruency alongside an interaction between control setting and congruency for separated stimuli. For integrated trials, control settings showed no effect, suggesting that stimuli were processed as single objects, rather than separate dimensions. Interference was observed in incongruent trials and naming shapes proved more difficult than reading

words when an incongruent distractor word was presented, irrespective of integration. Error rates further indicated that integration magnified the impact of congruence and highlighted the functionality of attentional capture in congruent trials. Overall, results suggest that spatially integrating verbal and non-verbal information successfully produced stimuli where both dimensions were processed as a single, coherent object.

Introduction

The Stroop effect (Stroop, 1935) is one of the most researched phenomena in psychological research. In its most basic form it describes the difficulty experienced by participants when attempting to name the ink colour of incongruous colour words, such as responding “green” to the word ‘red’ written in green ink. There is also a small facilitating effect (responding slightly faster to ‘red’ written in red than ‘bench’ written in red), but it is generally outweighed by the level of interference observed from irrelevant colour distractors (Stroop, 1935). The Stroop effect has also been established to occur with the use of geometric shapes (Compton & Flowers, 1977), in translation tasks between languages (De Houwer, 1998), in numerosity judgements (Windes, 1968) or in cross-modal variations (see MacLeod, 1991 for a review). Much research has been conducted on the conditions under which this interference effect occurs and how it can be manipulated. Flowers and Dutch (1976) discovered that allowing participants to focus on a single ink colour, such as picking out only words written in red, eliminated interference from incongruous colour words. Equally, no interference was observed when participants were asked to merely verify the presence of a particular colour without requiring it to be named (Risko, Stolz, & Besner, 2005). Flowers and Dutch (1976) further reported that when participants were asked to select chromatically adjacent colours (e.g. yellow, orange, red), no interference was found. When the task was changed, however, to chromatically non-adjacent colours (e.g. green, orange, purple), interference effects re-emerged. The same pattern was observed with geometrical shapes. If a response was required to shapes that could be grouped based on feature similarity such as rounded versus straight features (circles, ovals and hearts versus squares, crosses and rectangles), no interference occurred from incongruous verbal labels, but when straight and rounded features were mixed, interference was found. It has also been shown that to a large extent the difficulty of completing the Stroop task arises from the ever-changing distractor. As both targets and non-targets are constantly changing within a small pool of stimuli, both positive and negative priming effects are likely to occur, resulting in faster responses if the target remains the same in two (or more) consecutive trials (Tulving & Schacter, 1990) and slower responses if the target was the distractor on the previous trial (Tipper, 1985). When the irrelevant colour word remains the same and only ink colour is changed, interference reduces significantly (Zajano, Hoyceanyls & Quellette, 1981). Similarly, if incongruent flankers remain identical throughout trials, congruency effects of facilitation and interference disappear (Morein-Zamir, Henik & Spitzer-Davidson, 2002).

A number of theories have been put forward to explain the occurrence of the Stroop effect. The speed-of-processing hypothesis has been proposed, which relates closely to explanations revolving around automaticity. The argument suggests that reading the verbal stimulus has, by means of practice, become an automatic response and cannot be inhibited, whereas identifying the ink colour of written text is not commonly practiced and thus requires greater effort resulting in an increase in processing time (Durgin, 2000). Resulting from this process of automatisation (Shiffrin & Schneider, 1977; Schneider & Shiffrin, 1977), the verbal information derived by automatically reading the distractor becomes available as a potential competing output, owing to its closes semantic relationship with the target, before the verbal label associated with the ink colour can be retrieved and selected as a response. Parallel distributed processing models are able to model this type of processing quite accurately as the strength of a response to a previously encountered stimulus accounts for the response speed to a great extent. Surprisingly though, manipulation of stimulus onset asynchrony has shown no reduction of interference in Stroop experiments (McLeod, 1991) considerably weakening the speed-of-processing argument.

These theories tie in closely to the response competition hypothesis (Durgin, 2000, De Houwer, 2003). The main interference arises from the stimulus-response incompatibility between the target dimension and the required output dimension, although DeHouwer (2003) found that stimulus-stimulus compatibility between the distractor and the target also adds to the overall effect. In particular, the task requires a verbal response to a visual stimulus, while trying to ignore an irrelevant verbal distractor. The difficulty arises from ignoring the irrelevant verbal stimulus in favour of the required verbal response matching the visual target. Since both the distractor and required output use the same modality, while the target makes use of a different input channel and therefore needs to be translated into the required output dimension (Logan & Zbrodoff, 1998). Confusion arises easily during combined efforts towards target selection and distractor suppression, putting additional demands on the attentional system. Interference is substantially reduced when target and output dimension use the same modality, such as in experiments where a button press labelled with a colour patch is required instead of a verbal response (Pritchatt, 1968, Wheeler, 1977).

The magnitude of the Stroop effect can furthermore be reduced through dilution. Kahneman and Chajczyk (1983) reported that identifying the colour of a bar in the presence of an incongruous colour distractor was facilitated by also having a second, neutral distractor present within the display. However, where the actual distractor word was the colour carrier, Cho, Lien and Proctor (2006) found that dilution was only observed if the neutral distractor rather than the colour distractor was printed in the to be named ink colour, but no effect was found for an entirely irrelevant second distractor (also see Risko et al., 2005). The effect of dilution is reduced as the number of irrelevant distractors increases (Risko et al., 2005) and disappears if the location of the colour target is cued pre-trial (Mitterer, La Heij & Van der Heijden, 2003). With increasing size of the distractor set, spontaneous involuntary processing of all irrelevant information becomes less likely since the system cannot handle it and irrelevant information therefore fades into the background with less attention directed to it. Intrusion from a smaller set is more likely since both target and distractor(s) can be easily scanned with a single gaze (Verghese & Pelli, 1992; Dehaene, 1997). On the contrary, when location uncertainty is eliminated, attention can be immediately and successfully focused, thus preventing distractors from being processed.

In an attempt to reduce the level of Stroop interference, other studies have aimed to assess the conditions under which it is strengthened. Hereby, a common manipulation is the integration or separation of target and distractor and their effect on performance. In flanker tasks, which are somewhat similar to the Stroop paradigm, but usually place distractors on either side of the target stimulus, a pattern quite similar to that of Stroop interference is observed (Mordkoff, 1996), resulting in substantial interference when flankers are incompatible with the required response (Eriksen & Schultz, 1979). It should be noted, however, that although flankers are separate from the target, they are usually displayed in close proximity and their impact diminishes with increased spatial separation (Flowers & Stoup, 1977; Bradlyn & Rollins, 1980). Roelofs (2012) found that both words written in coloured ink and white words printed on coloured blocks produced the expected Stroop-type interference effect. However, when both integrated and separated stimuli were investigated in direct comparison, integrated items were shown to produce a greater level of interference than separated ones (Didi-Barnea & Shakuf, 2011) and integrated distractors proved more difficult to ignore (MacLeod, 1998). Wühr and Waszak (2003) used two blocks of colour, one serving as a target and one serving as a distractor and found that incongruent colour names caused greater interference when integrated into the target than when integrated into the distractor or presented freely in the background. Similar findings were presented by Risko et al. (2005) who reported that in a display of words, distractors only produced interference effects when they were integrated into the target, but not when they were presented in a separate location. Manwell, Roberts and Besner (2004) argued that cueing target location, as well as keeping the target and distractor physically separate, assists participants in keeping them informationally separate and thus aids independent processing and disregarding the irrelevant distractor. Naturally, this effect of integration is not limited to the colour word Stroop task, but equally occurs when geometrical shapes are used as stimuli, with congruous or incongruous shape words printed either inside or outside the target shape (Flowers & Stoup, 1977). Compton and Flowers (1977) also reported negative priming effects following incongruous trials.

Studies have further suggested that in a display that contains both global and local features, global features will be given processing priority before finer detail captures attention (Navon, 1977; Stirling & Coltheart, 1977). Using a display of large letters made up of smaller versions of a different letter and asking participants to name either the large or the smaller stimulus, Stirling and Coltheart (1977) discovered that visually confusable stimuli lead to greater interference than those of acoustic similarity, that is, the letter E made up of small Fs resulted in greater interference than the letter E comprised of small Ds. However, Martin (1979) amended the design of the stimuli and found that if the small letters creating the large target letter were fewer and slightly larger in respect to the global shape, the processing pattern is reversed and local features now gain priority over global ones. Finally, it has been argued that attention can be consciously targeted towards either global or local processing, but that this will result in significant processing cost for the unattended dimension (Kinchla, Solis-Macias & Hoffman, 1983).

Attention and Capture

Attention – in particular visual attention – is a vital part of human information processing, and efficient allocation of attention is integral to everyday functioning (Corbetta & Shulman, 2002). A number of theories have been put forward to explain how attention is directed throughout the visual field. Object-based theories (Barsalou, 1987) suggest that attention consists of two stages; a pre-attentive stage, which serves to segment the visual field into whole objects based on Gestalt principles and previous knowledge and experience, followed by a focal attentive stage where full attentive resources can only be effectively allocated to a single object at a time. In turn, discrimination based theories (Allport, 1971) suggest a dimensional approach to attention. They propose that while different dimensions are additive and can be attended to at the same time, different properties on the same dimension cannot. For example, while people can equally well process and make judgements about form and colour, they are less efficient at making concurrent colour judgements (Duncan, 1984). Note that these two theories are not mutually exclusive since different judgements of colour or form are commonly based on processing of different objects. Finally, spatially based theories (Posner, Snyder & Davidson, 1980) propose that attention is focused on a single area within the visual field, not unlike a spotlight shone in the dark, and that focal attention is only applied to the lit area at any given time. Yet, Duncan (1984) presents strong evidence supporting an object-based approach, reporting that two objects cannot be equally well attended even if they are superimposed in the same spatial location.

While some researchers suggest that attention is needed for both voluntary and involuntary action to occur (Yantis, 1998; Corbetta & Shulman, 2002), others have suggested that routine actions do not require attention but are carried out as a result of automatisation (Norman & Shallice, 2000). Norman and Shallice (2000) argue that focused attention is only needed if habitual behaviour is broken, such as not swallowing food after chewing, holding one's breath or taking a different route home. They suggest that attention is also needed for tasks, which have not been automated (e.g. learning to ride a bike), critical decisions (e.g. picking the right moment to cross the road) and potentially dangerous situations (e.g. driving in poor visibility). Rensink, O'Regan and Clark (1997) support this idea and suggest that attention paid to visual surroundings is largely based on schematic activation, while a complete mental representation of the visual scene is never constructed and even small changes can easily go unnoticed when unattended (also see Simons & Levin, 1997, 1998). Posner and Boies (1971) propose that conceptual mental activation on its own does not restrict processing capacity, but that attentional resources are only called upon if specific processing or mental manipulation is required to obtain a stimulus-evoked response. Wickens (1981) suggests that this lack of exhaustive processing may come about as a result of limited attentional capacity. He argues that dividing attention becomes more difficult if one of two concurrent tasks is substantially more demanding than the other. Thus, while experienced drivers are often able to drive and hold down a conversation simultaneously, sudden events on the road are likely to interrupt conversation and a particularly engaging or emotionally arousing topic of discussion can result in deterioration of driving performance. Furthermore, attentional resources are almost impossible to divide when two different inputs compete for the same channel, such as simultaneously listening to two separate conversations (Cherry, 1953; Cherry & Taylor, 1954; Hugdahl, Westerhausen, Alho, Medvedev, Laine & Hämäläinen, 2009). This view is primarily described as the structural view of attention (Broadbent, 1958; Welford, 1967; Keele, 1973). In contrast, capacity theories suggest that human information processing itself is limited regardless of input channel and only a small amount of information can be processed at any given time (Knowles, 1963; Moray, 1967; Kahneman, 1973). This assumption is supported by findings presented by Verghese and Pelli (1992) who suggest that visual attention can only be directed to a very small amount of information at once equalling no more than 30 to 60 bits of display information.

An important distinction in the allocation of attention is the route through which information is attended. Hereby, a distinction is made between top-down and bottom-up processes where the former is goal directed, effortful, intentional, resource-limited and easily suppressed while the latter is stimulus driven, automatic, unintentional and independent of current goals or memory load (Desimone & Duncan, 1995 and Eriksen & Eriksen, 1974, respectively). In other words, it describes the difference between deliberately searching for a sign indicating where the nearest restroom can be found and automatically becoming aware of the sound of glass smashing on the floor in the next room (Pratt & Hommel, 2003; Ruz & Castillo, 2002). While top-down processing can result in missing potentially relevant, but highly unexpected stimuli (Simons & Chabris, 1999), this does not exclude that currently unattended information will be processed and will influence behaviour (Simons, 2000; Moore & Egeth, 1997).

Attentional resources are challenged when two objects need to be processed simultaneously but not sequentially. This difficulty is thought to arise at the early processing stage since no interference in short term storage or response selection is observed for sequentially encoded information. Theeuwes (1992) proposed that some dimensions capture attention more readily than others; for example, colour captures attention more easily than form. Yantis (1998) suggest that motion captures attention automatically, which may be based on an evolutionary need for action in response to sudden movement in one's close proximity. Remington, Johnston and Yantis (1992) confirmed that environmental cues interfere with attention regardless of intent and cannot be ignored, although Warner, Juola and Koshino (1990) reported that participants were able to prevent peripheral cues from capturing attention following extensive practice (following an average of 4500 trials; also see Bacon & Egeth, 1994). Desimone and Duncan (1995) propose that attentional capture of goal relevant objects is achieved through a combination of bottom-up and top-down processing. The mere knowledge of what one is looking for is insufficient for the object to be detected unless a pop-out effect is present. Nevertheless, the argument has been made that attentional capture may be highly contingent on current goals (e.g. Yantis, 1993b; Remington, Folk & McLean, 2001; Folk, Leber & Egeth, 2002), that is when looking for a friend's green jacket in a crowd, other green items are likely to draw attention involuntarily, while red, blue or yellow items will not. These control settings are highly adaptable and can be altered at short notice. If, for example, your friend were to call you to let you know they were not wearing their green jacket today, but a red sweater instead, attention would immediately switch to be captured by red rather than green objects as you continued searching the crowd (Lien, Ruthruff & Johnston, 2010). While these rapid shifts in attention are functional in that they direct resources to potential targets (Pratt & Hommel, 2003) they can also results in significant cost and slow down detection of the true target (Folk et al., 2002; Moore & Weissman, 2010). The process of attentional capture has been shown to be largely inclusive, rather than exclusive (Pratt & McAuliffe, 2002), that is the system is activated by features matching the to be detected target, rather than individually being deactivated for each non-matching stimulus. Hereby, each feature has the potential to capture attention even if not all target properties are met, i.e. when searching for a blue book, both blue and book-shaped objects can independently lead to involuntary capture of attention (Pratt & McAuliffe, 2002). While combinations of separate dimensions can be easily processed (i.e. an items that is both blue and square), simultaneous goals for the same dimension are thought not to be held with equal strength, that is, participants cannot search for either a red or blue book with equivalent efficiency (Folk & Anderson, 2010; Oberbauer, 2002, 2003; Garavan, 1998; Monsell, 2003).

While substantial evidence for contingent attentional capture has been presented (Folk et al., 1992; Ruz & Castillo, 2002; Yantis, 1993b; Lien et al., 2010), an argument has also been made that highly salient stimuli have the potential to capture attention regardless of current control settings (Hickey, McDonald & Theeuwes, 2006; Kim & Cave, 1999; Yantis, 1993a, 1993b, 1996). During non-guided investigation of a visual scene Itti, Koch and Nieburg (1998) suggest that areas of interest are attended to in order of decreasing saliency to ensure priority processing of conspicuous events, which may be relevant for responsive action. Once the most salient aspect of a scene has been investigated and inhibited, attention can move on to the next most salient area (Itti & Koch, 2000). Visual onset may be unique in capturing attention as sudden appearance poses a number of challenges for the attentional system (Ruz & Castillo, 2002; Yantis, 1993b). When each item in a display could be a potential target, new items need to be assessed for target properties, which is unlikely to happen peripherally (Folk & Remington, 1999). Thus, novelty may be a determining factor in whether or not attention will be captured. If the new object, however, does not possess any of the target properties, attention is quickly withdrawn again (Ruz & Castillo, 2002). Further studies have shown that the interfering effect of onset can be overridden by ensuring spatial certainty, that is if participants know where the target will appear, onset in other areas of the visual field does not capture attention (Ruz & Castillo, 2002; Yantis, 1993b; Yantis & Jonides, 1990). These findings have been challenged by Folk et al. (2002) who pointed out that under conditions of spatial certainty, only one object could function as the potential target. They showed that when spatial uncertainty was eliminated, but more than one object was present within the target area, onset once again captured attention even outside the target area. In turn, Simons (2000) suggests that onset may capture attention only if participants are actively looking for targets with sudden onset or attention is not closely focused on another goal. Thus, attentional capture of irrelevant stimuli may be a measure of focus of attention rather than the captive capacity of stimulus properties. Yet, equally, it should be noted that it is likely that in real world settings, part of the attentional system may always be on the lookout for relevant outside stimuli as real life surroundings are much more prone to sudden events that are likely to require attention and behavioural adaptation. Research has suggested that dimension-relevant cues can act as effective primes (Moore & Weissman, 2010) even if they lack predictive validity (Folk et al., 1992; Pratt & Hommel, 2003). Folk et al. (1992) found that spatial cues capture attention even when participants are aware that cues will never predict target location. This design does, however, present two serious issues. For once, a predictor that never predicts the target location is not random and can still serve as a reliable indicator of which location to exclude when searching for the target. Secondly, cues appearing in the real world are almost never random. When searching for a particular exit on the motorway, looking out for signs and following arrows is usually the right thing to do. Simons (2000) further points out that laboratory studies of contingent capture may lack validity as they are typically concerned with how well participants are able to ignore an irrelevant, expected stimulus, while most real life scenarios are more concerned with people needing to be aware of relevant, unexpected stimuli such as a pedestrian stepping onto the road from behind a parked car. This scenario requires attention to be directed immediately to the unexpected event in order to successfully adapt current behaviour to the new circumstances, in this case pressing the brake and slowing down the car. He further points out that while participants may have been instructed to ignore a particular stimulus, this does not automatically guarantee that these instructions will be followed and it can not be excluded that participants may occasionally direct attention to an expected stimulus voluntarily even though they know it to be irrelevant.

Contingent attentional capture has not been observed solely on the basis of dimensional features, but has also been found to occur on a conceptual level. In a recent study Wyble, Folk and Potter (2013) reported that when looking for a specified object, category members have the potential to involuntarily capture attention during search, even if they share no visual similarities with the target. While Folk et al. (1992) have suggested that entirely exogenous capture of attention may never occur this claim has been repeatedly refuted by Ruz and Castillo (2002) who suggest that attentional capture cannot be exclusively contingent on control settings as it can occur in the absence of a control set. A less strict approach has been put forward by Awh, Belopolsky and Theeuwes (2012) suggesting that exogenous capture may occur only on dimensions that are irrelevant to the current control settings. Thus, when looking for a static blue object, irrelevant stimuli such as sound or motion still have the potential to involuntarily attract attention as non-goal relevant channels remain open and input is not filtered for these dimensions (Broadbent, 1982). Finally different brain activation patterns have been found for goal-directed and involuntary allocation of attention. While top-down allocation of attention mostly shows activation in the superior frontal and intraparietal cortex, attentional capture of salient items is associated with activation in the inferior frontal and temporoparietal cortex (Corbetta & Shulman, 2002). These findings support the theoretical distinction of different types of attention.

Inattentional Blindness and Blindness to Change

While attention is clearly important for assessing our environment, it can be subject to rather astounding failures. These phenomena include instances of inattentional (Hyman, Boss, Wise, McKenzie & Caggiano, 2010; Mack, 2003; Most, Simons, Scholl, Jimenez, Clifford & Chabis, 2001) and change blindness (Simons & Levin, 1997; Franconieri & Reimer, 2000). Inattentional blindness refers to the failure of observers to detect major events in their environment or visual field, which should intuitively be highly noticeable and capture attention easily. Simons and Chabris (1999) asked participants to watch a short video of a non-professional basketball game and count passes while doing so. They reported that almost half of their sample failed to notice either a woman with an umbrella or a person in a gorilla costume crossing the screen during the game (also see Neisser, 1979). This leads to the conclusion that when attention is highly focused, unattended events are blocked out and are not processed even if they occur in plain sight. This relates closely to the limits to visual attention capacity suggested by Verghese and Pelli (1992). On the other hand, Change blindness refers to a situation where people fail to notice a substantial change to their surroundings or visual field. Simons and Levin (1998) conducted a real life experiment where an experimenter engaged a stranger in a conversation by asking for directions. A group of builders then interrupts the conversation by carrying a large board between the experimenter and the pedestrian. During this moment of separation, the experimenter is switched for a different person of similar height, build, dress and the same gender. Again, only half the people in this scenario noticed that their conversation partner had been swapped while he other half simply carried on giving directions. Laboratory based studies of change blindness often use comparable methodologies of disrupting attention, switching between the original and changed stimulus by inserting a blank screen, replacing stimuli during a saccade or eye blink, by eliciting a momentary shift of attention to a different location or by means of momentary occlusion (Rensink, 2002). Results have suggested that only a minimal lapse of attention is required for change blindness to occur (Rensink, 2001) and that changes often go undetected even if participants are aware that a change has taken place and are actively searching for it (Rensink, 2002). As a result, Simons and Rensink (2005) argued that focused attention is needed to detect a change but that even large changes can go unnoticed if attention is not allocated. Wheeler and Treisman (2002) suggested that focused attention is required but often not sufficient to detect a visual change. Triesch, Ballard, Hayhoe and Sullivan (2003) propose that change detection is highly contingent on task demands. They further suggest that change may go unnoticed in a currently attended object if the change is irrelevant to current attentional goals. Finally, a study by Simons, Franconeri and Reimer (2000) observed change blindness without disruption of attention in a gradual change occurring over the duration of 15 seconds, given that both scenes are equally plausible. This was found for both object deletion and addition as well as changes in colour.

These findings suggest that people may exhibit a tendency to see what they expect to see and use new information to confirm rather than disprove already held beliefs about the world around them. It also highlights the importance on context effects when interpreting visual stimuli (Olson & Chun, 2002). This supports the assumption that a full mental representation of the world is built by means of a constructionist approach (Hertel & Ellis, 1979). However, Rensink (2001) suggests that stimulus plausibility may have an important role to play. He highlights that the types of changes engendered in the experimental materials commonly lack validity and are counter-intuitive; that is, people do not change their identity half way through a conversation, walls do not move, chimneys do not suddenly appear or disappear and cars do not change colour. He further argues that the assumption of environmental consistency is an important mechanism to prevent cognitive overload. Missing details can be filled in and full awareness of minute details is not usually required to successfully and accurately interpret a scene. Essentially, looking for the types of changes occurring in these experiments would be a complete waste of cognitive resources since knowledge and experience of physical laws make them impossible to occur in the natural world. In relation to the stimuli used in the current work it suggests that having a contextual relationship between verbal and non-verbal stimulus features may lead to significant contextual cueing allowing non-verbal features to be interpreted on the basis of verbal content and vice versa, even if neither dimension is fully processed in isolation.

The Present Experiments

Results obtained in Chapter 1 showed that while integrated stimuli failed to produce a recall benefit and took significantly longer to process, a distinct processing pattern was observed. Recall for integrated stimuli was not affected by exposure time, yet recall scores most closely resembled pictures. This suggests that factors other than mere exposure allowed integrated items to be recalled successfully. To reduce the confounding effect of stimulus familiarity the current chapter aimed to investigate the effect of integration and segregation of verbal and non-verbal information in two experiments, using a basic shape Stroop paradigm. As indicated in the literature review, integration of dimensions has a large role to play in Stroop tasks and its impact has been shown in a series of experiments stretching over a number of decades. Having established in Chapter 1 that integrated stimuli may be subject to different processing mechanisms than words alone or separated items and having further observed that simpler task instruction resulted in a pattern of results more in line with previous research findings, the two experiments described in the present chapter were designed using only basic shapes to allow for a more basic exploration of the effect of integration and segregation of verbal and non-verbal information. Four shapes were chosen in an effort to limit potential targets and reduce uncertainty regarding the identity of integrated stimuli. A Stroop type task was chosen to investigate the effect of integration in a well-known paradigm, which will allow meaningful conclusions to be drawn in close relation to earlier findings. This design furthermore allows investigation of the effect of manipulating control settings by focusing attention on either the verbal or non-verbal dimension of the stimuli independently and comparing the two in order to get a measure of which type of information is processed as a primary source of information. In traditional Stroop tasks, participants are usually asked to respond to only one of the stimulus dimensions, either the verbal or the non-verbal features of the target. In the current experiments, participants' control settings will be altered to respond to the verbal dimension on half the trials and the non-verbal dimension on the other half of the trials. Altering control settings in this way will allow for processing of both verbal and non-verbal information to be understood independently in both separated and integrated stimuli. Setting attention to each dimension in turn will reveal the potential of verbal and non-verbal information to capture attention involuntarily when presented alongside the other. Task instructions were kept simple, requiring a single identifying response by button press, in order to minimise the effect of the unfamiliar format of integrated stimuli. In addition, manipulation of congruency between the two dimensions was used to determine the level of automaticity at which each dimension is processed (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). If the verbal dimension is processed with greater efficiency, larger interference should be observed when responding to shapes, while the opposite pattern would be expected if non-verbal information is processed at a higher level of automaticity. Hereby, previous findings have suggested that conceptual information may be more readily extracted from pictures than words (Potter, 1976). If the evidence presented in previous studies holds true, then greater physical integration of verbal and non-verbal aspects should lead to increased mental integration when processing stimuli (Gajewski & Brockmole, 2006). This would be evidenced by facilitatory effects in congruent trials and inhibitory effects in incongruent trials (Stroop, 1935; MacLeod, 1991). While these effects are likely to be present in separated trials, it is expected that integrated stimuli would produce stronger Stroop effects as a result of response competition (Durgin, 2000; De Houwer, 1998) and an increased chance of involuntary attention capture of the irrelevant dimension (Wyble et al., 2013) as well as greater difficulty experienced when separating relevant from irrelevant information (Gajewski & Brockmole, 2006). In other words, the greater the proximity between the target and the to be ignored dimension, the greater the chance for information from the irrelevant dimension to be processed and result in substantial interference when selecting the correct response. Since the required response in the current experiments is non-verbal (button press), it was furthermore expected that responding to words would result in greater interference in incongruous trials than responding to shapes (Logan & Zbrodoff, 1998). It has been repeatedly shown that the observed Stroop interference results largely from the competition between selecting a relevant from an irrelevant response, where both the required response and the distractor are on one dimension, while the target is presented on a different dimension (Durgin, 2000; De Houwer, 1998). Thus in the traditional Stroop task a verbal response (naming the ink colour) is required to a non-verbal target (the ink colour) while a verbal distractor is present (the irrelevant colour word).

The primary aim of the current experiments is to investigate the effect of presenting verbal and non-verbal information in both integrated and separated formats and to assess how each dimension is processed by means of altering control settings between verbal and non-verbal target dimensions. The effect of congruency was examined in line with standard Stroop practice. The chapter is also designed to establish whether integration of verbal and non-verbal information into a single object is achieved successfully or whether dimensions continue to be processed independently.

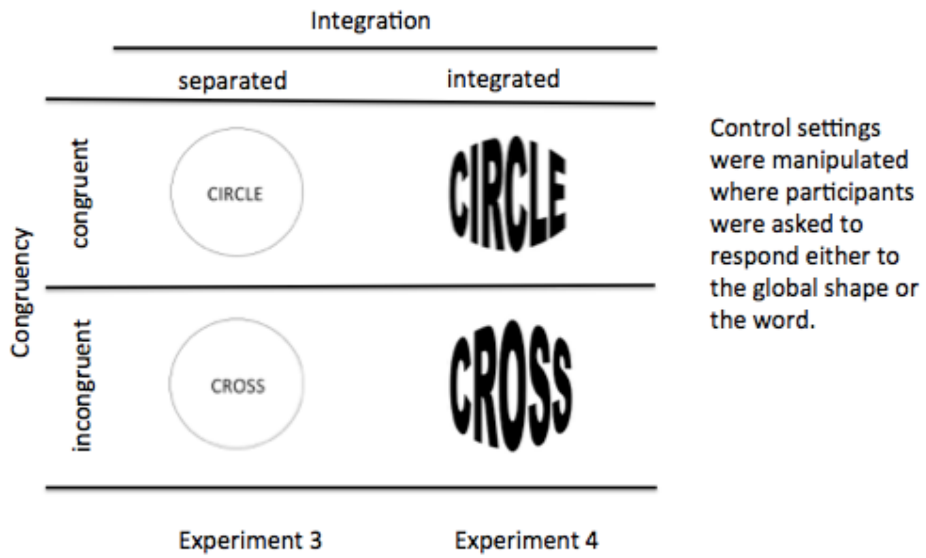

Figure 3.1: Conditions and examples of stimuli in both experiments.

Experiment 3

Experiment 3 was designed to test the effect of congruency and control setting in non-integrated stimuli. Only separated stimuli were used in this study, where words were shown written inside outlines of geometrical shapes. While other studies would have used this format as an integrated version, the current work argues that full integration is not achieved under these conditions. While words are contained within the shape both objects are still visually distinct and attention can relatively easily be directed to only one of the two while ignoring the other. Dimension congruency was manipulated where words and shapes were either congruent (the word circle written in the outline of a circle) or incongruent (the word circle written in the outline of a square). Control setting was manipulated where participants were asked to respond to the verbal dimension in half of the trials (focus on words) and on the non-verbal dimension in the remaining trials (focus on shapes). Unlike in Chapter 2, the effect of native language was not explored in this chapter. With the use of only four basic shapes and a sample of participants studying at a British university, it is highly unlikely that any significant impact of native language would be detected.

It was expected that the established pattern of faster reaction times for congruent compared to incongruent trials would be observed (Stroop, 1935). Congruent information is usually processed faster and more easily since it fits into an expected set of features and helps to complete an already activated concept or schema (Brewer & Treyens, 1981). Since a non-verbal response was required via button press it was also expected that adopting a control setting for non-verbal rather than verbal aspects of the targets would lead to faster reaction times than when participants are required to respond to the verbal dimension (Pritchatt, 1968; Wheeler, 1977). While distractors are expected to capture attention to an extent, the physical separation between verbal and non-verbal information should keep attention more easily focused on the target dimension (Didi-Barnea & Shakuf, 2011). Any observed capture, expressed in response speed differences, is likely to occur as a result of conceptual capture in this experiment (Wyble et al., 2013) since stimuli are visually distinct but conceptually related.

Methodology

Participants. A total of 47 undergraduate psychology students participated in the experiment in exchange for course credits. The majority of respondents were female (33; 70.2%). Ages ranged from 18 to 38 with a mean age of 20.83 years (SD=4.09 years). Just over half of the sample identified themselves as native English speakers (51.1%) while the remaining students spoke English as a second language. The majority of the sample was White (53.2%), followed by Chinese (19.1%), Black (12.8%) and Asian (12.8%). Only one participant reported other ethnic origins (2.1%).

Design. Two factors were investigated in a repeated measures design: control setting, where participants responded either to the word or the shape, and congruency, where words and shapes were either matched or mismatched. Control setting was varied in two counterbalanced phases, while congruency was randomly varied across all trials. Reaction times and response accuracy were measured.

Apparatus. The experiment was presented on Superlab version 4.0.7b running on eMacs (PowerMac6,4) with PowerPC G4 processors (1.25GHz) using OS X. Stimuli were displayed on 17" flat screen monitors at a resolution of 1280x960px.

Stimuli. Sixteen separate stimuli were used, with each item being displayed four times during each test phase, adding up to a total of 128 trials. Four basic shapes were used to create stimuli: circle, square, cross and heart. Shapes were displayed as an outline and words were written inside the outline. While targets were viewed in close proximity to each other, full integration was not achieved in this instance. Congruent trials were at a ¼ ratio. Examples of stimuli are shown in Figure 3.2 below.

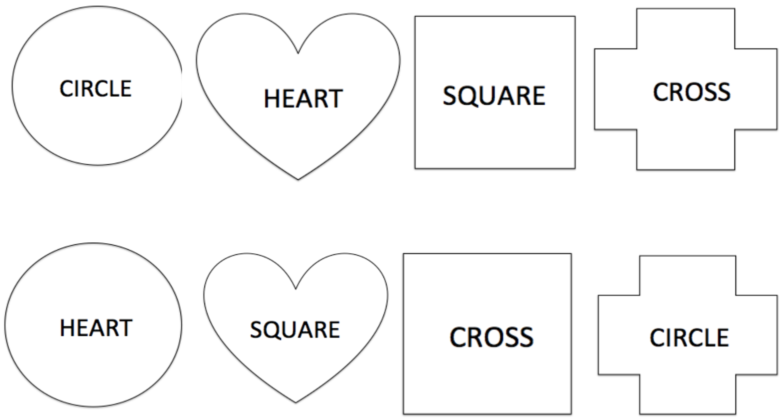

Figure 3.2: Examples of separated stimuli. Top row: congruent. Bottom row: incongruent.

Procedure. Participants provided demographic data and consent in writing before starting the experiment. They then completed the experiment individually on a computer. During each of the two test phases in each experiment participants completed a total of 64 trials. They were asked to respond to the relevant dimension by button press, responding C to circle, V to heart, B to cross and N to square. Buttons were assigned based on physical proximity on the keyboard to enable easy reach. Participants were initially instructed to either respond to the shape or the word during one of the test phases before switching their attention to the other dimension during the second test phase. They were made aware that there was no time limit for responses, but were asked to respond as quickly and accurately as possible.

Results

Two 2x2 repeated measures ANOVAs were run to investigate the effect of control setting (word vs. shape) and congruency (congruent vs. incongruent) on both reaction times and error rates. Descriptive statistics displaying means and standard deviations for both dependent variables can be seen in Table 3.1 below.

Table 3.1: Means and standard deviations of reaction times and error rates for native and non-native speakers across presentation formats.

		reaction times		**error rates**	
		mean	**SD**	**mean**	**SD**
congruent	words	1221.28	472.08	4.99	0.77
	shapes	1034.72	269.15	4.46	0.51
incongruent	words	1215.45	438.34	4.94	0.46
	shapes	1182.36	336.2	5.93	0.58

Reaction times. A significant main effect was found for congruency, F(1, 34)=4.981, p=0.032, η_p^2=0.128, where congruent items produced faster response times than incongruent items. A marginal effect was observed for control setting, F(1, 34)=3.716, p=0.062, η_p^2=0.099, falling just short of significance, where words took marginally longer to responds to than shapes. A significant interaction was also found for control setting and congruency, F(1, 34)=7.415, p=0.01, η_p^2=0.179. Simple effects for the interaction were examined using Bonferroni post-hoc testing. The analysis revealed that in the congruent condition shapes yielded faster response times than words, p=0.008. No difference was observed for incongruent stimuli, p=0.59. In addition when responding to shapes, congruent stimuli yielded faster reaction times than incongruent items, p<0.001. No difference was observed when responding to words, p=0.906. Results are shown in Figure 3.3 below.

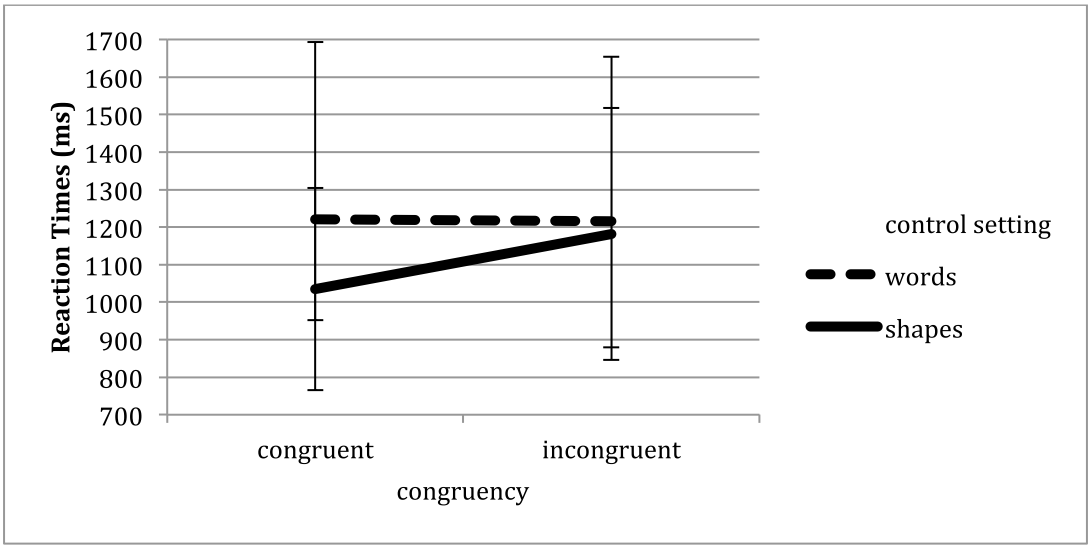

Figure 3.3: Interaction of reaction time scores between control setting and congruency for separated stimuli; means and standard deviations of reaction times

Error rates. No significant main effects on error rates were found for control setting, F(1, 34)<1, p=0.942, η_p^2<0.001, or congruency, F(1, 34)=1.045, p=0.314, η_p^2 =0.03. No significant interaction was found between control setting and congruency, F(1, 34)=1.154, p=0.29, η_p^2=0.033. Findings are shown in Figure 3.4 below.

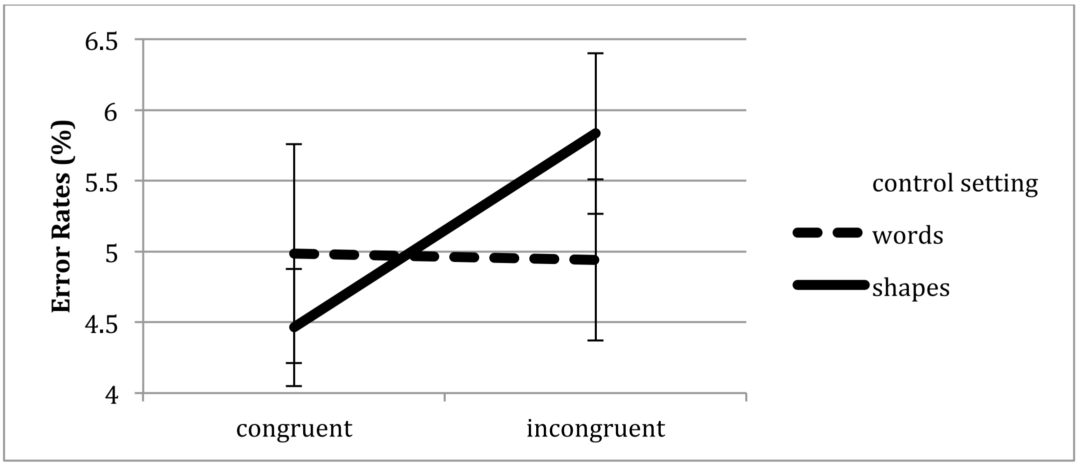

Figure 3.4: Interaction of error rates between control setting and congruency for separated stimuli;

means and standard deviations of error rates

Discussion

Experiment 3 investigated the processing of verbal and non-verbal information presented simultaneously with alternating control settings determining which dimension needed to be responded to in a Stroop-type experiment with geometrical shapes where verbal and non-verbal dimensions were kept spatially separate. Data collected from Experiment 3 served to reveal information of how verbal and non-verbal information is processed in a separated design. This approach allowed for the results to be compared to novel, integrated items in Experiment 4 and to determine whether the same or different effects are at play when level of integration is altered. Congruency was manipulated and participants were tested on responses to both the verbal and non-verbal dimension. Reaction times and error rates were recorded to assess how separated verbal and non-verbal dimensions were processed in a non-integrated design. As predicted, faster reaction times were found for congruent trials. Shapes produced faster reaction times in congruent trials, while words were unaffected by manipulation of congruency. No significant effects were found on error rates, although shapes did show a slight trend towards higher levels of accuracy in congruent trials, while words remained entirely unaffected.

Alternating control settings between verbal and non-verbal information was vital to assess the potential each dimension has to involuntarily capture attention from the other. It will also serve as a measure of whether integration of dimensions was successfully achieved. In the current study marginally faster reaction times were observed for shapes compared to words, but congruency was found to benefit control settings for shape substantially more than control settings for words. Congruent shapes were responded to faster than either congruent words or incongruent shapes. This highlights both the importance of stimulus-response compatibility as well as the impact of stimulus-stimulus congruence in the Stroop task. It has been previously shown that providing a non-verbal response to a non-verbal target increases response speed (Logan & Zbrodoff, 1998). Furthermore, this is in line with earlier findings suggesting that Stroop interference can be significantly limited or even eliminated if the target and required task response can be processed through the same channel (Pritchatt, 1968; Wheeler, 1977). Even when buttons used in the current study did not map directly onto the shapes, that is, they were labelled by irrelevant letters rather than images corresponding directly to the target shapes, a small benefit in processing time was observed. However, it is likely that only some degree of direct mapping occurred, with part of the response process based on retrieval of a verbal label, as shape response speed did not differ significantly from word responses when congruency effects were disregarded. When considering the impact of congruence, it emerged that while shape responses for incongruent items showed no difference from word responses for either congruent or incongruent items, shape responses for congruent trials showed a significant increase in response speed, suggesting that the presence of feature congruency was more helpful when processing non-verbal rather than verbal targets. This might further indicate that attentional capture occurs more easily when the distractor is fully compatible with the target, rather than being only conceptually related but not referring to the same concept. Another possibility for this greater benefit is the way in which we use language. While activation of a verbal label is not necessary for conceptual activation or comprehension (Brown & McNeill, 1966), it is essential for communication (Bloom, 2000). Since humans are conditioned from very early childhood to use language in order to make themselves understood (Pinker, 1994), verbal information may be more intuitively given priority during processing when a task response is required. Even tasked with a non-verbal response format, it is possible that verbal information would be used to guide decision making, particularly under conditions when the required output cannot be mapped directly from target to response.

The small trend towards higher error rates in incongruent trials for shape response provides additional evidence of attentional capture. The findings clearly support the idea that attentional capture occurred on a conceptual level in this instance (Wyble et al., 2013). Since no featural similarities exist between the verbal and non-verbal stimuli, feature-based capture cannot occur. It therefore follows that any attentional capture would have occurred as a function of conceptual similarity, where both the verbal and non-verbal information referred to geometrical shapes. This is furthermore supported by the observation that there was little effect for verbal targets for which conceptual activation is slower and more effortful (Potter, 1976). Finally, these results confirm the earlier assumption that verbal information is processed more easily and efficiently (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977) and offer support to an explanation of the Stroop effect revolving around speed of processing and automaticity, where capture was observed from verbal distractors when responding to non-verbal targets, but not vice versa. The faster access to verbal information likely as a result of life-long conditioning to use verbal communication (Bloom, 2000; Pinker, 1994) resulting in reading automatisation (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977), and is thus less prone to interference from external attentional capture. On the other hand, as previously argued, when viewing a geometric shape the corresponding verbal label may not necessarily be retrieved, while activation of phonological nodes upon viewing a verbal stimulus is almost guaranteed to happen.

Experiment 4

Experiment 3 revealed the traditional Stroop pattern of response competition as an effect of congruency manipulation, however, even with the use of a non-verbal response format, interference was observed from verbal distractors only, while non-verbal distractors showed no impact. This likely occurred due to the inability to directly map targets onto responses. Similar results have been obtained in a large variety of studies over a number of decades and are well established (MacLeod, 1991). As previously highlighted in the introduction, the extent to which these effects occur is subject to the level of integration between the target dimension and the distractor dimension (Didi-Barnea & Shakuf, 2011). While varying levels of integration have been explored in past research (Eriksen & Schultz, 1979; Mordkoff, 1996; Roelofs, 2012), full integration of target and distractor into a single combined item has been subject to limited testing only. While full integration has been achieved for colour distractors, the same method has not been comprehensively applied to distractors using geometrical shape. In order to assess the effect of full integration of verbal and non-verbal information on performance in a shape Stroop test, Experiment 4 replicated the previous experiment, but replaced separated with integrated stimuli. It was expected that results will mirror those of Experiment 3, but that integrated stimuli would be more susceptible to facilitation and interference effects and a more pronounced pattern would emerge in this instance, enabling capture from both verbal and non-verbal distractors. In the current experiment, attentional capture can occur on both a conceptual and featural level when responding to either the verbal (word) or the non-verbal (shape) dimension of a target, since attention will inevitably have to be directed towards the whole object in which letter shape and object shape are intrinsically interlinked and form a visually integrated single object. This is likely to render the irrelevant shape or word substantially harder to ignore (Didi-Barnea & Shakuf, 2011). Thus, if integration of verbal and non-verbal information is achieved successfully, responses to the verbal level should now be equally affected by changes in congruency as a result of both dimensions being processed as a single object.

Furthermore, it is expected that error rates will show an effect of congruency in this instance, as integration will lead to greater difficulty in suppressing the task-irrelevant dimension (MacLeod, 1998).

Methodology

Participants. The same participants were used as in Experiment 3.

Design and Apparatus. The same factors were investigated as in Experiment 3 and data was collected for response latencies and error rates. Both control setting and congruency were again assessed within participants. The same apparatus was used as in the previous study.

Stimuli. The same basic shapes were used to create stimuli for Experiment 4. Individual letter position for each word was altered to form one of the four shapes to results in full integration of verbal and non-verbal dimensions. Congruent trials were at a ¼ ratio. The same number of trials was used as in Experiment 3. Examples of stimuli are shown in Figure 3.5 below.

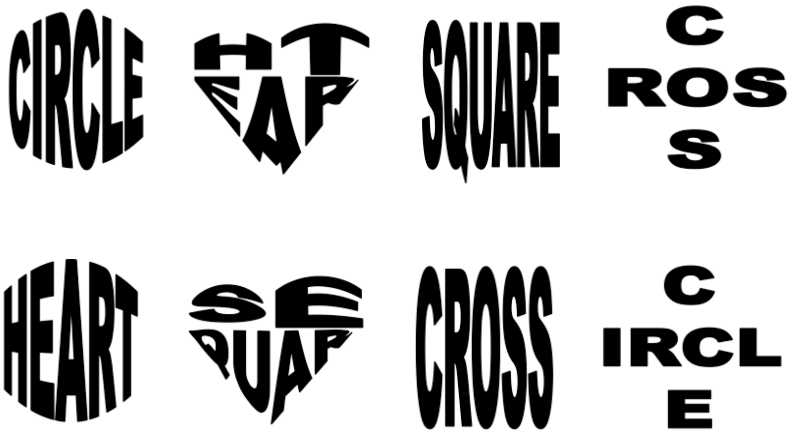

Figure 3.5: Examples of integrated stimuli. Top row: congruent. Bottom row: incongruent.

Procedure. In addition to the previous study, Experiment 4 also contained an initial practice phase in an effort to reduce confounding effects resulting from the unfamiliar presentation format for integrated stimuli. No actual words were used for the practice phase, but shapes were made up of Xs or Os instead. For the experimental phases, the same procedure was employed as in the previous study. The order in which experiments and experimental phases were completed was counterbalanced.

Results

As before, two 2x2 repeated measures ANOVAs were run to investigate the effect of control setting and congruency for both dependent variables. Descriptive statistics displaying means and standard deviations for both dependent variables can be seen in Table 3.2 below.

Table 3.2: Means and standard deviations of reaction times and error rates for native and non-native speakers across presentation formats.

	reaction times	**error rates**

		mean	SD	mean	SD
congruent	words	1358.74	91.82	3.041	0.41
	shapes	1300.36	75.2	2.37	0.13
incongruent	words	1470.62	77.26	5.18	0.75
	shapes	1426.5	93.06	6.76	0.59

Reaction times. A significant main effect was found for congruency, F(1, 36)=11.225, p=0.002, η_p^2=0.238, where congruent items were once more responded to faster than incongruent stimuli. No significant main effect was found for control setting, F(1, 36)<1, p=0.464, η_p^2=0.015. No significant interaction was observed between control setting and congruency, F(1, 36)<1, p=0.841, η_p^2=0.001. Simple effects calculated through Bonferroni post-hoc tests showed that congruent items yielded faster response times for both words, p=0.045, and shapes, p=0.01. Results are shown in Figure 3.6 below.

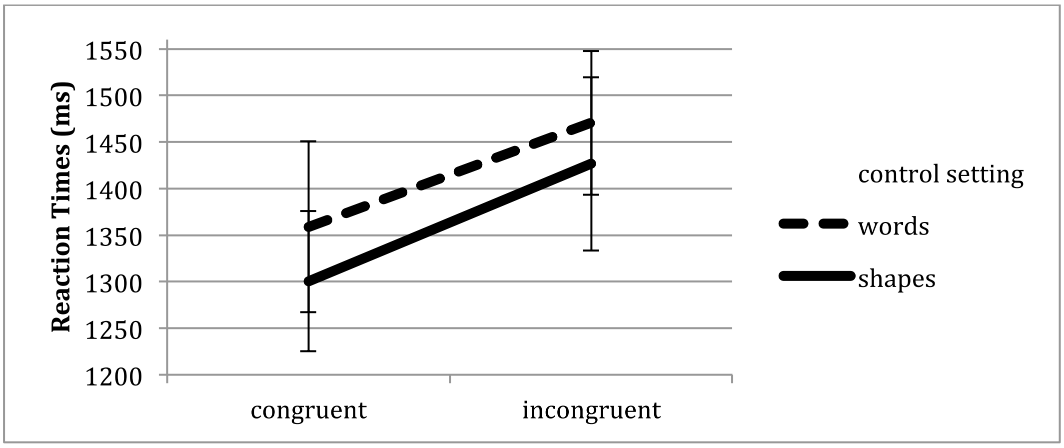

Figure 3.6: Interaction of reaction time scores between control setting and congruency for integrated stimuli; means and standard deviations for reaction times

Error rates. A significant main effect on error rates was found for congruency, F(1, 36)=9.292, p=0.004, η_p^2=0.205, where congruent stimuli produced higher levels of accuracy than incongruent items. No significant main effect was found for control setting, F(1, 36)<1, p=0.73, η_p^2=0.003. A marginal interaction was found between control setting and congruency, falling just short of significance, F(1, 36)=3.881, p=0.057, η_p^2=0.097. Simple effects derived from Bonferroni post-hoc analysis for the interaction revealed that congruent items resulted in a slight advantage in response accuracy for shapes, p=0.006, although words also showed lower error rates in congruent than incongruent trials, p=0.015. Results are displayed in Figure 3.7 below.

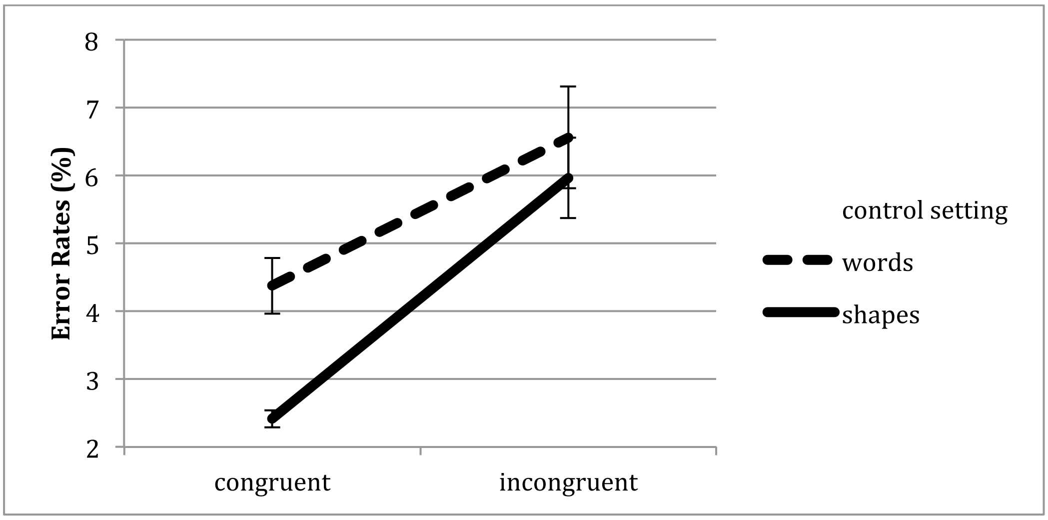

Figure 3.7: Interaction of error rates between control setting and congruency for integrated stimuli; means and standard deviations of error rates

Discussion

Building on the results from Experiment 3, Experiment 4 was designed to test how effects observed for separated items are translated to integrated stimuli. Both verbal and non-verbal information was combined into a single stimulus and responses to both dimensions were tested in a Stroop task as in Experiment 3. It was expected that overall more pronounced effects would be observed compared to Experiment 3 as a result of increased difficulty when separating the relevant response dimension from the irrelevant distractor dimension (Didi-Barnea & Shakuf, 2011). When verbal and non-verbal information was integrated, only congruence showed a significant effect on reaction times with control setting not showing any impact. This suggests that feature integration was achieved successfully and stimuli were processed as single objects. No difference in processing speed was observed regardless of the dimension participants were asked to respond to. Although shapes were responded to slightly faster in both congruent and incongruent trials, the difference was not significant. Congruent trials produced faster responses regardless of control setting. The lack of an effect of altering control setting revealed that both dimensions now had equal potential to capture attention and that both verbal and non-verbal information was processed with equal efficiency. This strongly suggests that dimensions were fully integrated and perceived as single integrated targets.

Reaction times were overall slower than for the separated items, further supporting the assumption that stimuli were processed as single items from which relevant information needs to be extracted at greater processing cost than if dimensions were displayed separately (Didi-Barnea & Shakuf, 2011).

With the use of integrated stimuli, error rates were now clearly affected by congruency with congruent trials leading to significantly higher accuracy than incongruent trials for both word and shape control settings. A slightly higher benefit was observed for shapes compared to words which is likely to be a result of the compatibility between input and output dimensions, both of which are non-verbal for shapes (Logan & Zbrodoff, 1998), as previously discussed in Experiment 3. The impact of feature integration on error rates furthermore supports the notion that dimensions were integrated successfully as the presence of irrelevant information now led to a drop of performance on a simple task (MacLeod, 1998). Greater effort is required to reach the correct response through separating relevant from irrelevant information and the irrelevant dimension has an increased chance to influence response selection, leading to the increase in error rates seen in Experiment 4.

The higher error rates recorded in the incongruent condition for both words and shapes, is in line with expectations of attentional capture occurring on both a conceptual and featural level when verbal and non-verbal information is integrated into a single object. Since words were now altered to form global shapes, in addition to conceptual attentional capture, featural capture could occur since directing attention to identify the word would also direct attention to the global shape and vice versa. The smaller effect on words compared to shapes could be explained by the previously discussed slower conceptual activation for verbal compared to non-verbal stimuli (Potter, 1976).

Combined Analysis

While experiments 3 and 4 presented above provide insight into both separated and integrated items individually, no direct comparison between levels of integration in relation to control setting and congruency has been tested so far. To investigate the interaction between congruency and integration, data were collapsed across the two experiments and an additional four 2x2 repeated measures ANOVAs were run to examine the effect of congruency and integration on reaction times and error rates for responses under both control settings.

It was expected that integrated items would produce slower reaction times as a result of increased difficulty when separating relevant from irrelevant information

(Didi-Barnea & Shakuf, 2011). It was also expected that interference will be stronger for non-verbal control settings while trials with a verbal control setting will be less affected, since verbal information is likely to be processed faster than non-verbal information (Durgin, 2000; Dunbar & MacLeod, 1984).

Reaction Times

Words. A significant main effect was found for integration, F(1, 34)=4.418, p=0.043, η_p^2=0.115, where integrated words produced slower reaction times than non-integrated words. No significant main effect was found for congruency, F(1, 34)=2.243, p=0.143, η_p^2=0.062. No significant interaction was found between congruency and integration, F(1, 34)=1.156, p=0.290, η_p^2=0.033. These findings are illustrated in Figure 3.8 below.

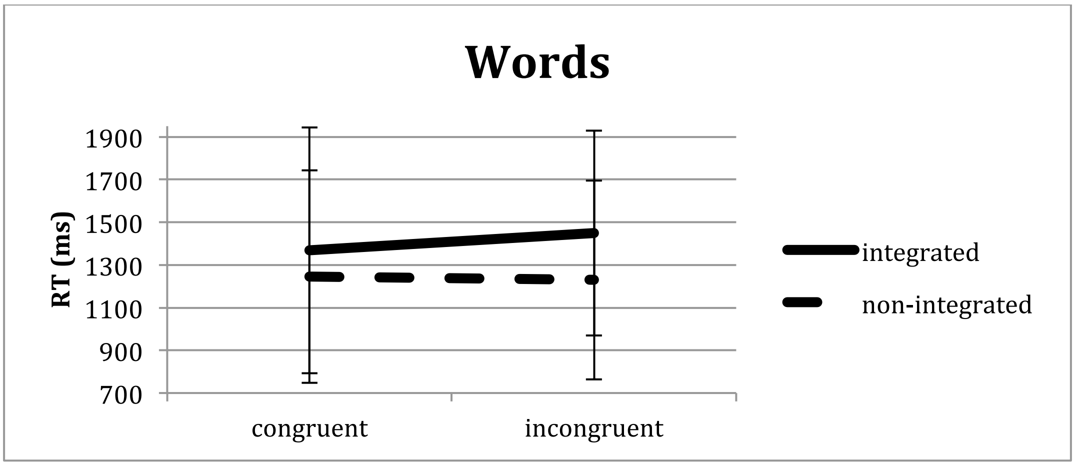

Figure 3.8: Interaction of congruency and integration in reaction times for words; means and standard deviations for reaction times

Shapes. Significant main effects were found for congruency, F(1, 36)=23.962, p<0.001, η_p^2=0.4, where incongruent shapes produced slower reaction times, and integration, F(1, 36)=15.296, p<0.001, η_p^2=0.298, where integrated shapes took longer to respond to than non-integrated shapes. No interaction was found between congruency and integration, F(1, 36)<1, p=0.743, η_p^2=0.003. This is shown in Figure 3.9 below.

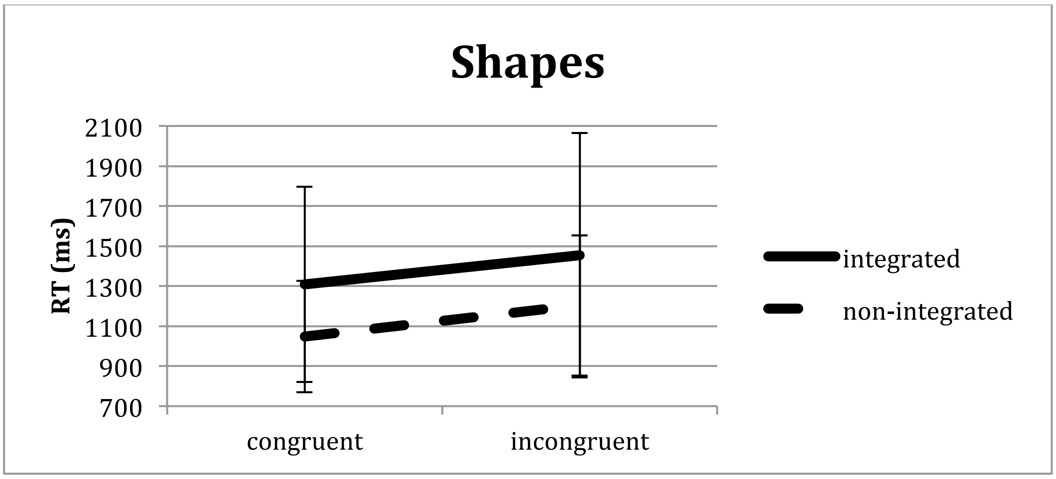

Figure 3.9: Interaction of congruency and integration in reaction times for shapes; means and standard deviations for reaction times

Error Rates

Words. No significant main effect was found for congruency, F(1, 34)=1.819, p=0.168, η_p^2=0.051, or integration, F(1, 34)<1, p=0.614, η_p^2=0.008. A significant interaction was found between congruency and integration, F(1, 34)=5.526, p=0.025, η_p^2=0.14. Simple effects calculated through a Bonferroni post-hoc test revealed that for integrated words congruent items produced higher accuracy than non-integrated items, p=0.008, while no effect was observed for separated words. Results can be seen in Figure 3.10 below.

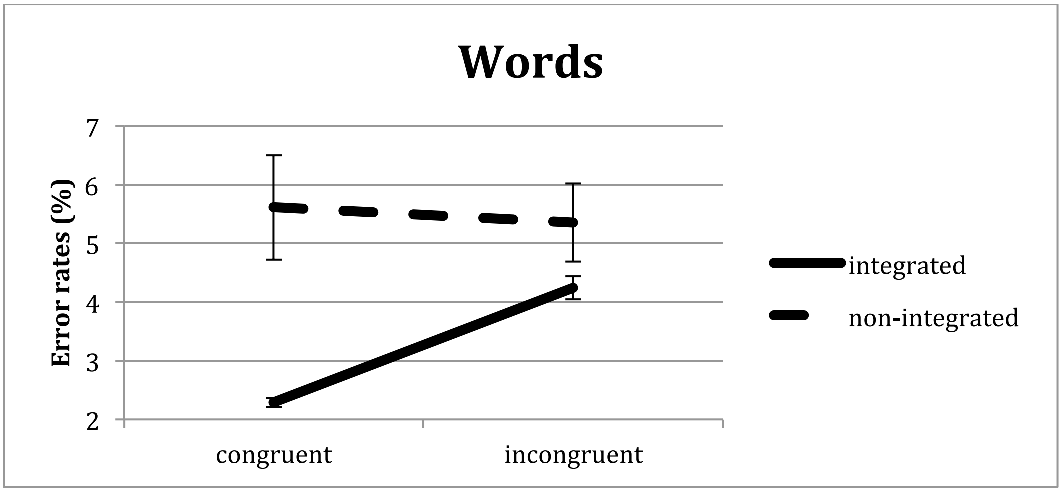

Figure 3.10: Interaction of congruency and integration in error rates for words; means and standard deviations for error rates

Shapes. A significant main effect was found for congruency, F(1, 36)=6.164, p=0.018, η_p^2 =0.146, where congruent shapes produced higher accuracy than incongruent items. No significant main effect was found for integration, F(1, 36)<1, p=0.555, η_p^2=0.01, and no significant interaction was found between congruency and integration, F(1, 36)=2.07, p=0.159, η_p^2=0.054. This is illustrated in Figure 3.11 below.

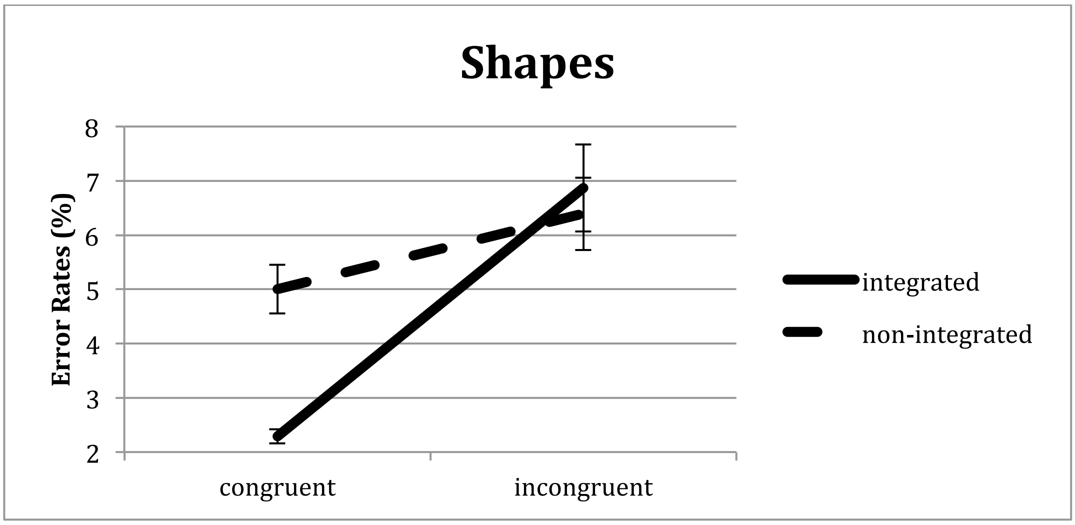

Figure 3.11: Interaction of congruency and integration in error rates for shapes; means and standard deviations for error rates

Discussion

The combined analysis of all data served to investigate the relationship between congruency, integration and control setting directly. Data analysed so far suggested that integrated stimuli successfully combined verbal and non-verbal information into a single object, as indicated by a more balanced pattern of effects for integrated stimuli with attentional capture observed for both control settings. The analysis of collapsed data thus aimed to highlight the full impact of this manipulation by directly comparing integrated and non-integrated stimuli. As previously indicated, integrated items took longer to respond to independent of control setting. This is likely a result of increased processing demand when separating the two dimensions to enable participants to select the relevant response (Didi-Barnea & Shakuf, 2011). With letters making up the shape of the object, it becomes impossible to visually separate the two dimensions since they occupy the same physical space and form a single perceptual object.

Reaction times revealed a strong impact of integration in particular. Integration showed a significant impact for both verbal and non-verbal control settings, whereas congruency only impacted significantly on trials with a shape control setting. Slower reaction times were observed for incongruent compared to congruent trials, for both control settings and both levels of integration, although the effect was more pronounced for shapes and occurred most reliably for integrated items. This might suggest that when control settings were set to shapes as opposed to words greater benefit was derived from congruent trials. These findings mirror the commonly found pattern in Stroop type tasks (Stroop, 1935; MacLeod, 1991). Results are compatible with an explanation based on faster access to verbal information (Dunbar & MacLeod, 1984) as well as accounts of reading automatisation (Shiffrin &

Schneider, 1977; Schneider & Shiffrin, 1977; Hasher & Zacks, 1979). Alternatively, it may suggest that verbal information captures attention more easily than a non-verbal distractor when the distractor information is the same as the target information and therefore fits the search criteria for the required response. That is, when trying to name a geometrical shape, the corresponding verbal label needs to be retrieved; in congruent trials this label is easily accessible by attending to the to be ignored distractor. Attentional capture mechanisms may therefore be activated during mental search when the desired target is detected, consequently cutting the search process short and resulting in faster response times in these trials.

Error rates provided further insight into processes involved in extracting information from integrated and separated stimuli. A control setting for verbal information produced higher accuracy in congruent trials when dimensions were integrated, while no such effect was observed when control settings were focused on non-verbal information, where congruent stimuli resulted in higher accuracy independent of integration. This shows that while non-verbal targets benefited from congruency, regardless of level of integration, verbal stimuli were affected only when the non-verbal congruent information was directly integrated into the target. Congruent shapes did not aid responses to verbal targets when they were shown separated from the target word. These findings make a strong case for the importance of feature integration when processing information from different dimensions. They further support the notion that integrated items are processed differently from separated dimensions and that potential processing benefits could be derived from meaningfully integrated stimuli (Garner, 1976). The results may furthermore indicate that verbal stimuli could be less vulnerable to conceptual capture, although featurally similar objects can succeed in capturing attention. It is clear that reading is subject to highly feature-driven processing. Letters often closely resemble each other and need to be identified with high accuracy to be interpreted correctly. The representational nature of language should also be considered, which relies purely on mapping arbitrary verbal labels onto real world concepts while lacking the direct representational capacity of pictures (Bloom, 2000). This also supports the idea of qualitatively different processing of letters compared to other visual objects (Lachmann, 2002; Zegarra-Moran & Geiger, 1993).

Finally, the results indicate that trials on which there is a potential for both featural and conceptual capture are more likely to result in intrusion from the unattended dimension, while conceptual capture alone yields a smaller effect. Traditional accounts of capture have commonly been based on featural capture only (Remington, Folk & McLean, 2001; Folk et al., 2002). The current study provides support for featural capture, but also confirms the capacity for conceptual capture, although non-verbal targets were shown to be more vulnerable to this, possibly due to faster conceptual spreading activation for these items (Potter, 1976).

General Discussion

The two experiments presented here used manipulation of control settings to assess whether verbal and non-verbal information could be combined into a single object by means of spatial integration. Findings from Chapter 2 suggested that stimuli, which combine both verbal and non-verbal features, may be processed in a way distinct from either items containing both dimensions in a separated format or items containing only a single dimension. Experiment 2 showed that simplifying encoding instructions by omitting a distractor categorisation task, yielded results, which more closely reflected previously established findings including a recall benefit for pictures (Stenberg, Radeborg & Hedman, 1995) and a memory enhancing impact of added exposure time (Loftus & Kallman, 1979; Tversky & Sherman, 1975). As a result, stimuli in the current experiments were simplified, using only four elementary geometrical shapes as targets, to investigate the effect of integrating verbal and non-verbal information at a basic level, while eliminating other confounding factors as far as possible. A Stroop task paradigm was used to enable assessment of both verbal and non-verbal processing by manipulating control settings. The Stroop task is a widely researched phenomenon, which allows for meaningful comparison of current results to previous findings as well as highlighting effects obtained as a result of integration. In order to examine the impact of feature integration, Experiment 3 used visually separated stimuli while Experiment 4 assessed performance with fully integrated targets.

Despite providing an initial practice phase to reduce the effect of an unfamiliar presentation format, integrated stimuli were still responded to more slowly than separated items, although it should be noted that this effect arose from shape responses only. The effect was present for both congruent and incongruent trials. It should also be noted that the practice phase was short and performance was not analysed to determine whether practice improved response time and accuracy. More extensive practice might help to eliminate the response time difference between integrated and separated stimuli (MacLeod, 1991), which would allow for a clearer picture of the effect of integration without the confounding influence of presentation format. Practice data could be analysed to assess its effectiveness in familiarising participants with the novel, integrated presentation format. This would be helpful in determining how much of the delayed response is accounted for by the fact that the two stimuli may need to be separated before response selection can occur successfully (Didi-Barnea & Shakuf, 2011). However, it may be entirely possible that even with extensive practice no further increase in speed will be observed and that having to identify a single dimension from an integrated object will inevitably lead to a response delay as a result of the additional processing demand. In addition, it is highly unlikely that ease of reading integrated stimuli could be matched to ease of reading regular text following life-long practice.

When disregarding the level of integration, shapes yielded faster responses in congruent trials, while responses for incongruent trials showed no marked differences regardless of whether attention was directed at words or shapes. While it has been generally suggested that verbal stimuli are processed more readily, with a greater level of automaticity than non-verbal stimuli (Kahneman & Chajczyk, 1983) and are less prone to interference from non-verbal distractors (Carney & Levin, 2002), this has commonly been found in designs were a verbal output was required (Virzi & Egeth, 1985). The current findings suggest that the same may be true for a non-verbal response when target properties cannot be mapped directly onto the output dimension. In addition control settings for shapes benefitted more from congruent verbal distractors than vice versa.

While congruent items were recognised more accurately in integrated trials, no difference between congruent and incongruent stimuli was observed for the separated condition. This shows that integration did have a significant impact on the results, most likely due to increased interference where target and distractor could not be readily separated, resulting in a higher error rate in incongruent trials. This largely supports previous findings regarding the effect of integration of relevant and irrelevant dimensions (Didi-Barnea & Shakuf, 2011; Stroop, 1935; MacLeod, 1991). This further supports indicative findings discussed in Chapter 2 suggesting that integration of verbal and non-verbal information was achieved successfully and had a significant impact on stimulus processing. The delay in response times and increase in error rates provides substantial evidence that feature integration was achieved successfully and the overall low error rates show that both verbal and non-verbal information was processed effectively and meaningfully. Furthermore, if processing of the distractor dimension had not occurred, no interference or capture would have been observed. As expected, a more pronounced effect was observed in incongruent than congruent trials, affecting both reaction times and correct answers. These results may further suggest that attentional capture from a congruent distractor occurs more easily and can aid performance when information pertaining to the same concept is presented in an alternative format. In fact, the argument can be made that under these conditions failing to ignore a congruent distractor is highly functional and beneficial to task completion. In trials where the target and distractor are congruent both have equal potential to lead the participant to the correct response. It stands to reason that allocating attention and extracting information from both dimensions will enable faster task completion in this case (Paivio, 1971).

While significant interference effects are clearly at work in the Stroop effect, most people do actually manage to complete Stroop tasks successfully and error rates are generally low (Lovett, 2005). In fact, in the current study, the highest recorded error rates were approximately 6.8% for shape naming of integrated, incongruent stimuli and approximately 6.4% for shape naming in separated, incongruent stimuli. Lowest error rates were observed for word responses in congruent, integrated trials with approximately 2.3% and shape responses in congruent, integrated trials with approximately 2.4%. While the results highlight the importance of congruence between target and distractor (MacLeod, 1991) they also underline the mediating role of integration, with the effect of congruence on error rates magnified in integrated trials, leading to a significant interaction between the two variables.

In summary, the two experiments presented in this chapter investigated the impact of integration and congruency of verbal and non-verbal information, where response requirements are varied as a result of altering control settings. Following the inconclusive results from Chapter 2, a simpler approach was chosen, using only four basic geometric shapes. The findings confirm the previously formulated theory that integration of verbal and non-verbal information will lead to significant processing differences, expressed in both altered processing speed and error rates. The experiments furthermore confirmed that both verbal and non-verbal information can be perceived as a single object under conditions of full integration as indicated by highly similar results for integrated stimuli, independent of control setting. Results obtained here were highly compatible with earlier findings, showing faster reaction times and lower error rates for congruent compared to incongruent trials (Stroop, 1935) and more pronounced effects when responding to non-verbal compared to verbal targets (Ikeda, Hirata, Okuzumi & Kokubun, 2010). In addition, the results confirmed the central role of integration in producing these familiar patterns. Findings also provided important insight into mechanisms of attentional capture, confirming the potential of both featural and conceptual capture as well as highlighting conditions under which capture is functional and purposeful as is the case in congruent Stroop trials. Having established an effect of integration in basic stimuli using only simple geometrical shapes suggests that comparable effects should occur in more complex target items, similar to those used in Chapter 2. Therefore, the following chapter will focus once again on more complex stimuli. Although the previous results suggested that exposure time was not likely to be a factor in item recall for integrated stimuli, introducing timed as opposed to self-paced trials might allow further insight into how integrated dimensions are processed. This will also serve to conclusively exclude an attentional explanation of recall. In addition, the congruency manipulation will be retained as this allows for a measure of the extent to which the alteration of global shape impacts reading when featural modification is relevant as opposed to irrelevant to the target's meaning.

CHAPTER 4

The Effect of Congruence and Exposure Time in Incidental and Intentional Encoding

Abstract

Findings presented in Chapter 3 suggested that featural integration of words and geometric shapes was achieved successfully as indicated by the lack of an effect when manipulating attentional control settings for integrated stimuli. While varying control settings affected separated stimuli, integrated items were processed as single objects and alternating control settings yielded equal levels of attentional capture. Consequently, the present chapter investigates the potential for conceptual processing in more complex stimuli more similar to those used in Chapter 2. In four experiments, participants were presented with integrated stimuli in which congruent and incongruent verbal and non-verbal information was combined and investigated along standard font items. Experiment 5 investigated incidental recall using a distractor task. Results mirror those of Experiment 1 with long response latencies and low recall rates. Experiment 6 omitted self-paced in favour of pre-timed trials and results showed that integrated stimuli could be successfully processed with only 2000ms exposure. Experiment 7 investigated free recall of all presentation formats under intentional encoding instructions with a 2000ms exposure. Results showed a clear benefit for congruent and control stimuli but no impact on incongruent stimuli.

Finally, Experiment 8 extended exposure time to 4000ms per trial resulting in improvement for all presentation formats. Congruent and control stimuli performed on par and both still outperformed incongruent stimuli. In addition, results highlight the importance of native language with native speakers showing clear evidence of processing integrated congruent information significantly more efficiently than non-native speakers. Findings further highlight the role of encoding strategy and exposure time.

Introduction

The ability to produce and comprehend language is a fundamental tool for meaningful human communication. New vocabulary is typically acquired quickly and accurately. When a novel object is introduced and labelled, it can be recalled successfully by both children and adults even a month after a single exposure, particularly if relevant information is meaningfully integrated (Bloom, 2000). Words refer not only to objects, actions or ideas, but also the concepts they relate to. Human beings have a natural propensity to organise the world into meaningful segments and recognise concepts long before their labels are learnt (Cohen & Strauss, 1979, Pinker, 1994). Babies as young as 4½ months old show a clear ability to distinguish between familiar and novel stimuli (Roder, Bushnell, & Sasseville, 2000). Nevertheless, to achieve meaningful communication, concepts need to take verbal form, particularly if the object in question is not physically present or a concept of an abstract nature is being discussed. These verbal labels merge with the concept, eventually becoming synonymous with it. Conceptual representation and processing has been the focus of much research and a wide range of theories has been discussed (Hull, 1920; Rosch, 1973; Barsalou, 1983; Murphy, 2004, Medin, Lynch & Solomon, 2000).

Conceptual Processing

While language is an important tool that allows communication and thought exchange, it rarely conveys the full richness of information or the complexity of the concepts it aspires to describe (Bloom, 2000). As such, while a concept can be captured in a single thought (Tovée, 1994) that may incorporate physical attributes, such as colour, shape or size, sensual experiences such as touch, smell or sound, as well as emotional associations of joy, anger or fear, this complexity cannot be satisfyingly expressed in a single word. While two speakers may refer to the same physical object or abstract concept, their understanding and experience of it may differ drastically. This wider activation of associated information is known as conceptual processing. Conceptual processing is integral to human thought and has been found to be the most frequent type of processing in the brain and activation of different brain areas is observed for processing concepts or merely processing word meaning (Pulvermüller & Hauk, 2006). Conceptual activation may occur in both category associated processing or a process of free association. It encompasses semantic processing, mental simulation, assessing functional relatedness or visual similarity to name but a few (Simmons, Hamann, Harenski, Hu & Barsalou, 2008). Conceptual information processing is a continual process and occurs throughout the brain's resting state (Binder, Frost, Hammeke, Bellgowan, Rao & Cox, 1999). Conceptual thinking is characterised by not focusing solely on a single object or thought but leading instead to wider activation, which can include a range of other functionally or thematically related objects or ideas (Kalénine, Mirman, Middleton & Buxham, 2012). When processing our surroundings, the brain is continually engaged in seeking familiarity and testing the scene for schema compatibility (Brewer & Treyens, 1981; Pezdek, Whetstone, Reynolds, Askari & Dougherty, 1989), regardless of current task requirements (Orgs, Lange, Dombrowski & Heil, 2007). Incoming perceptual information only strengthens conceptual processing under conditions where compatibility can be found and stimuli can be meaningfully integrated (Kaschak, Madden, Therriault, Yaxley, Aveyard, Blanchard & Zwaan, 2005).

A number of theories have been put forward to explain how concepts are processed and understood. Barsalou (1984) proposed the idea that concepts have different 'slots' that are filled with information to access specific instances of a concept. He argues that concepts are not pre-set but rather are constructs in working memory that draw on long-term memory information and are re-formed for each occurrence to fit the current circumstances. Other theories have argued for category membership judgements (Hull, 1920), exemplar accumulation (Medin & Shaffer, 1978) and prototype comparison (Posner & Keele, 1968), but all are subject to substantial academic challenge as discussed in Chapter 1. The present study will focus on concrete concepts and how they are processed. It stands to reason that if concepts are equally strongly associated with both a verbal and pictorial representation, providing both types of information together will lead to more effective processing and more holistic access to the target concept.

Picture versus Word Processing

While words and digits are the most abstract form of symbols used in everyday language, pictures can convey basic information about physical objects equally well or even more effectively than a verbal representation (Bloom, 2000). Pictures are usually designed to bear a strong resemblance to the object they represent and, for an established language user, are equally strongly associated with the corresponding word as they are with the object itself; that is to say word, picture and object are all intrinsically linked in our minds. While pictures generally allow faster access to a larger amount of information (Paivio, 1971), they also retain more room for interpretation and their meaning is not as unambiguous as for words (Bloom, 2000). Thus, any painting or drawing is essentially a man-made artefact, the full meaning of which is usually a result of the combination of the artist's intent and the observer's interpretation. Unlike words, however, pictures are capable of making use of basic identifying features such as shape and colour (Bloom, 2000). Colours are said to enable fast access of related information and are often strong determinants for an object's perceived nature, potentially reducing processing load under appropriate conditions (Xing, 2006).

As a result of their different nature, pictures and words undergo different encoding processes and pictures have repeatedly been shown to result in superior performance in recall tasks compared to words (e.g. Shepard, 1967; Blanc-Brude & Scapin, 1999, Stenberg, Radeborg & Hedman, 1995). This effect has been explained by a number of theories including Paivio's (1971) dual coding theory, which suggests that information is processed and encoded via both verbal and non-verbal pathways. He suggests that pictures will be processed more easily since they are readily channelled into these pathways while words will not as easily evoke an equally complex mental image. The effect is strongest for more concrete stimuli, as they will evoke more complex mental representations than abstract concepts (Hodes, 1994). Furthermore, pictures may be more adequately processed by the visual system than written stimuli (Stenberg, 2006) and have been shown to lead to a greater spread of activation of semantically related concepts (Stenberg et al., 1995). They contain more complex information than words alone and while this increases processing demand, it may also lead to a deeper level of encoding (Park & Mason, 1982). Finally, pictures lend themselves to parallel processing substantially better than text, which by its very nature must always be processed sequentially (Neisser, 1967). Pictures may furthermore benefit from a deeper processing level. Craik and Lockhart (1972) proposed three main levels of processing: structural, phonetic and semantic. The superior effect for semantic processing is observed independent of whether participants are aware of the subsequent recall test and is unaffected by offering strong incentives for recalling items processed on a more shallow level (Craik &

Tulving, 1975). More recently neurological evidence has shown that the mental processes associated with these levels occur in separate brain regions offering further evidence for their distinctiveness (Nyberg, 2002). Park and Mason (1982) found that pictures may be subject to deeper processing than words and according to findings by D'Agostino, O'Neill and Paivio (1977) pictures are less prone to levels of processing manipulations than verbal stimuli.

Explaining the Stroop Effect

Processing competition between verbal and non-verbal information has been examined widely in past research. Stroop experiments (Stroop, 1935; MacLeod, 1991) are examples of this type of research. Although the basic premise is simple, the Stroop task incorporates investigation into simultaneous processing of verbal and non-verbal stimuli, processing speed, stimulus congruence, response selection and competition, attentional capture and information integration. In its initial form, participants are required to look at a set of colour words printed in different coloured inks and are then asked to name the ink colour rather than read the word. In a vast number of past experiments it has been demonstrated that ink colour naming was significantly inhibited by the presence of a colour word distractor (see MacLeod, 1991 for a review). What these experiments show is that human information processing happens automatically and often too fast for the conscious mind to intercept processing channels before information has been taken in (Glenberg, 1997). Irrelevant information is processed involuntarily and an inhibitory process fails to prevent the undesired response (Hommel, Proctor & Vu, 2004). As variations of the Stroop effect have become more creative, substantial evidence for conceptual processing of stimuli has emerged. Stroop interference has been observed not only in straightforward colour words, but is equally present in naming non-words that are phonemically similar to colour words (Rayner & Posnasky, 1978) or words with a strong colour association such as 'grass' or 'blood' (Altman & Davidson, 2001). Naor-Raz and Tarr (2003) report that naming ink colour of words describing objects is faster if the ink colour is typical of the object; thus the response 'yellow' to the word banana printed in yellow is significantly faster than the response 'purple' to banana printed in purple. The same effect can be observed for an atypical colour if it has been previously activated by a contextual cue, such as responding 'white' to the word 'bear' printed in white after reading about a bear at the North Pole (Connell & Lynott, 2009; Olson & Chun, 2002). At the same time, typical colour responses remain equally facilitated independent of whether typical or atypical colour is cued and are not hampered by atypical colour activation (Connell & Lynott, 2003). Interference is observed when atypical colour is not cued but needs to be retrieved (Connell & Lynott, 2003) and when naming incongruent ink colour of colour-implied words such as 'sky' or 'grass' (Klein, 1964). The interference effect increases in strength the more strongly words are associated with certain colours (Scheibe, Shaver & Carrier, 1967). These findings clearly indicate that distractors are processed beyond mere orthographic recognition or phonemic activation but instead activate associated conceptual object properties, which result in the observed interference effects.

A variety of theories have attempted to explain the mechanisms underlying the Stroop effect; a notable example is the speed-of-processing hypothesis (e.g. Dunbar & MacLeod, 1984). It suggests that reading has, by means of practice, become an automatic response and cannot be inhibited, whereas identifying the ink colour is unpractised since it is irrelevant for text comprehension (Hommel et al., 2004). In support of this assumption, a reverse Stroop effect is not found under traditional conditions; that is, word reading is not affected by ink colour (Bloem & LaHeij, 2003). Meanwhile distractor words entirely irrelevant to a task are still processed to an extent (Wolford & Morrison, 1980). Studies have further found that naming colours takes longer than reading out colour words (Cattell, 1886) lending some support to the idea. While this has been successfully modelled in parallel distributed processing models (Cohen, Dunbar & McClelland, 1989), other research has found no effect of manipulating stimulus onset asynchrony (MacLeod, 1991). Furthermore, transforming colour words (presenting them written backwards and/or turned upside down) to slow down verbal processing also fails to eliminate the interference effect (Dunbar & MacLeod, 1984), suggesting that speed of processing is unlikely to be at the root of the phenomenon.

An alternative explanation is the response competition hypothesis (Glaser & Düngelhoff, 1984, Morton, 1969, Doehrman, Landau & O'Connell, 1978) in which two contradictory responses are said to compete for the same output channel. While words directly activate their spoken counterpart, the verbal label needs to be retrieved separately in colour naming. Hereby retrieval of the verbal label needs to be achieved after the correct colour concept has been mentally activated. While participants are usually fully aware of the colour they are trying to name and able to correct errors almost immediately, these errors still occur on occasion (Lovett, 2005). As such conceptual activation of the target colour does not guarantee successful retrieval of the colour label. When attempting to name a colour it is likely that the colour concept is fully activated, but additional processing time is needed to retrieve the corresponding verbal output (Brown & McNeill, 1966). The process may be further hampered since both stimuli (word and ink colour) use the same input channel, in this case the visual system, and both potential responses compete for the same output channel, in this case the verbal channel. In fact, interference effects are not observed when incongruent stimuli are presented via the auditory channel (Dyer, 1973).

In further support of this theory, it has been repeatedly found that when a button press is required in response to the ink colour, the Stroop effect is significantly reduced or even eliminated; in particular, if buttons are labelled using colour patches rather than words (Pritchatt, 1968, Wheeler, 1977). These findings led Virzi and Egeth (1985) to suggest a translational model; hypothesising that when input and output modalities are congruent, no interference occurs. In the traditional Stroop effect a transformation needs to occur from the perceptual to the verbal level. On the contrary, if buttons correspond directly to the colour concept, the response can be mapped directly, entirely bypassing the verbal channel. Furthermore, indicating whether two coloured rectangles are the same or a different colour compromises reaction times when the words 'same' or 'different' are printed on them but are unaffected if incongruent colour words or coloured Xs are printed in the same position (Egeth, Blecker & Kamlet, 1969). The model is also supported by Logan and Zbrodoff (1998) who recruited skilled typists to complete a slightly altered Stroop task, requiring participants to type instead of voice their ink colour responses. Under these circumstances interference increased compared to the traditional Stroop paradigm. When viewed under the translational hypothesis it becomes clear that an additional step of translation needs to occur in this experiment. Participants must first retrieve the verbal label for the target (ink colour) while simultaneously ignoring the irrelevant stimulus (incongruent colour word) and then translate that label into a typing response. Significant first letter latency but no typing delay was observed in these trials, suggesting that the underlying cognitive processes had been completed when participants began to type (Logan & Zbrodoff, 1998).

Nevertheless, speed of processing theories may not be entirely without merit. It has been consistently shown that reading words is significantly faster than naming colours (Cohen et al., 1990) or naming pictures (Glaser & Glaser, 1989). As with colours, picture naming is further impaired if an incongruent word is superimposed upon it, an effect that grows in magnitude if the distractor word is a member of the same category (Lupker & Katz, 1982). The effect, however, is reversed if the task is to categorise pictures (Glaser & Glaser, 1989). In this instance, pictures have a clear advantage over words, produce faster responses and incongruent words do not cause interference (Glaser & Düngelhoff, 1984). Facilitation is observed only if the distractor word and picture are identical, but not if they are members of the same category (Lupker & Katz, 1982). These findings are in line with Paivio's (1971) dual coding theory, suggesting that pictures have faster access to both verbal and non-verbal information and lead to faster semantic node activation. Thus, while words are accessed acoustically, semantic activation may only be accessed superficially according to the task demand; in contrast, pictures are more likely to activate their full semantic background and conceptual information but may not necessarily activate a verbal response (Brown & McNeill, 1966). This can further explain why distractors, which activate a wider semantic network result in greater interference by drawing potentially distracting information from a wider pool and reduced facilitation for categorisation tasks as a consequence of less specific activation. In contrast, cues for a narrow semantic range of associations show stronger facilitating effects in word naming as a result of activated information being more closely relevant to the target (Becker, 1980).

Although the evidence strongly suggest that there may be basic conceptual processes underlying the Stroop effect, conceptual processing has received relatively little attention in this particular context. Firstly, the Stroop effect is reportedly strongest when competing features are integrated into the same stimulus (Kahneman & Chajczyk, 1983) since this increases the likelihood of the distractor information being processed alongside the relevant dimension (Glaser & Glaser, 1989) and research has reliably shown that feature integration is one of the main aspects of object recognition and conceptualisation (Pomerantz & Pristach, 1989). Secondly, evidence that conceptual processing plays a large role comes from results obtained by Flowers and Dutch (1976). They found that if only one target colour (e.g. only words printed in red) needed to be identified, the written distractor did not impact on counting instances of words written red ink (also see Derks & Calder, 1969). The same was true for identifying targets printed in colours adjacent in the spectrum (e.g. red, orange and yellow). Interference did, however, occur when non-adjacent colours were given as targets (e.g. orange, green and purple), which cannot be conceptually linked. Flowers and Stoup (1977) conducted a similar study using shapes and shape words instead of colours, where incongruent words were written inside shapes. When participants were required to select a group of shapes, which had conceptually common features, such as circles, ovals, and hearts, all of which have a rounded appearance, or crosses, squares and rectangles, whose features are unanimously straight, no interference from incongruent words was found. If, on the other hand, no conceptual commonality could be found between the shapes, distractors impacted performance.

The Present Experiments

Findings presented in Chapter 3 suggested that featural integration of words and geometric shapes was achieved successfully as indicated by the lack of effect of manipulating attentional control settings for integrated stimuli. While varying control settings between verbal and non-verbal responses showed a clear effect for separated stimuli, integrated items were processed as single objects and alternating control settings no longer affected processing. Having established the successful integration of verbal and non-verbal information, the present chapter aims to show that the likelihood of full, conceptual processing increases if the entire concept can be accessed through a dual route pathway yielding both verbal and non-verbal activation, in accordance with the dual coding principle suggested by Paivio (1971). It is expected that presenting stimuli in an integrated format that uniquely lends itself to dual processing will result in a deeper trace and subsequent improved recall for those items (Craik & Lockhart, 1978). In particular the study examines how dual coding can be aided by feature integration (Hommel et al., 2004). The same design for integrated stimuli as presented in previous chapters is used, combining verbal and pictorial information into a single object. While the verbal and non-verbal routes of information processing have repeatedly been compared to each other, they have not previously been integrated into a single stimulus to encourage a more conceptually orientated encoding process. This approach should result in conceptual processing producing a deeper memory trace (Craik & Tulving, 1975), leading to better recall of integrated congruent information compared to integrated incongruent information and information presented in standard format.

Congruency is retained as a study variable from Chapter 3. Consequently, integrated stimuli will be referred to as either congruent or incongruent for the duration of this chapter. Preserving the congruency manipulation allows for the effect of integration to be examined in more complex stimuli in both congruent and incongruent trials. Furthermore, using congruent and incongruent stimuli with comparable featural manipulations would allow controlling for a recall advantage based solely on bizarreness or visual distinctiveness (McDaniel & Einstein, 1986; Hunt & Elliot, 1980) rather than conceptual processing based on congruent, meaningfully integrated information (Neville, Kutas, Chesney & Schmidt, 1986). It will furthermore allow for conclusions to be drawn about whether physically altered features of letters mostly produce processing noise by merely adding to the cognitive load or whether they can be meaningfully integrated and utilised in more complex designs. In addition, the current chapter will explore the role of incidental versus intentional processing and how encoding impacts retention of integrated items.

Due to the more complex stimuli used in this study, it is expected that a significant impact of native language will be observed. It has been repeatedly shown that the Stroop effect is more pronounced in native than non-native speakers (Fang, Tzeng & Alva, 1981; Dyer, 1971; Mägiste, 1984) and evidence further suggests that words are more strongly associated with their meaning in the first than the second language (da Costa Pinto, 1991; Harris, Aycicegi & Gleason, 2003).

Four experiments are presented in this chapter, examining the effect of feature integration and congruence on item recall. Experiment 5 compared congruent, incongruent and control stimuli in self-paced trials to test incidental recall, using a categorisation task. Experiment 6 again tested incidental recall, but omitted the distractor task, while Experiments 7 and 8 assessed intentional recall in pre-timed trials of two and four seconds, respectively.

Experiment 5

Results from Experiment 4 clearly demonstrated the mediating effect of integration on congruence. The current experiment preserved the previously used design, investigating both feature integration and congruence, while using more complex stimuli, similar to those used in Chapter 2. The purpose of Experiment 5 was to test the effect of varying dimension congruency of verbal and non-verbal information in complex, integrated stimuli and its effect on incidental recall. A series of written words referring to both natural and man-made concrete objects were designed that either resembled the object they described (congruent) or resembled a different, unrelated object (incongruent). Words were presented individually. According to the basic Stroop paradigm, congruent trials should be processed significantly faster than incongruent trials (Stroop, 1935). Based on studies of contextual cueing (Olson & Chun, 2002; Connell & Lynott, 2009), it can also be expected that congruent stimuli will be encoded with greater ease and will therefore result in superior recall. Incongruent words were expected to produce longest reaction times since they are both presented in an unfamiliar format (Olson & Chun, 2002) and contain irrelevant information adding to the processing load (Xing, 2006). Memory for these items is also expected to be poor since no integration of information can occur (Pomerantz & Pristach, 1989; Flowers & Dutch, 1976). Control stimuli in standard font were included to obtain baseline reaction times and recall scores. A picture only condition was omitted in Experiment 5 in favour of investigating the effect of manipulating congruence between verbal and non-verbal features. In addition, no significant differences between integrated and picture stimuli were observed in Experiments 1 or 2, rendering further comparisons of reduced interest.

Correct recall scores and reaction times were measured to assess recall accuracy and processing speed, respectively. The effect of native language was also assessed, due to the strong semantic component of the task, with native speakers likely having established significantly stronger associations between pictures and verbal labels (da Costa Pinto, 1991). The strength of this association is likely to be a primary determinant of successfully using integrated, congruent information to lead to increased recall.

In Experiment 5, a distractor categorisation task was once more given to participants to test incidental recall. Although based on results presented in Chapter 2, it is possible that using a distractor task may lead to unreliable results being obtained, it is equally possible that the introduction of a congruence manipulation would exert a larger effect on processing and differences between stimuli would emerge in spite of any confounding impact of task instructions (Noldy, Stelmack & Campbell, 1990). Results presented in Chapter 3 suggested that the impact of feature integration was substantially amplified by altering congruence. If a similar effect is obtained in the current experiment, this may serve to negate the confounding impact of the categorisation task.

Methodology

Participants. A total of 45 undergraduate students participated in the experiment on a voluntary basis. The majority of respondents were female (26; 57.8%). Ages ranged from 18 to 49 with a mean age of 21.91 years (SD=5.22 years). Sixty per cent of the sample (27) identified themselves as native speakers, while the remaining students spoke English as a second language. The majority of the sample was Black (35.6%), followed by Asian (28.9%), White (11.1%), Chinese (4.4%) and mixed ethnic heritage (2.2%). Four participants reported other ethnic origins (8.9%) and another four chose not to disclose their ethnicity.

Design. Congruency was investigated in a repeated measures design, where participants responded to stimuli of all types. Three conditions were used: congruent, where features matched the meaning of the word, incongruent, where features and meaning did not relate to each other and control, which consisted of words written in standard upper and lower case letters. Lists for each condition were blocked and block order was counterbalanced between participants. Words in each block were randomised. Native language was measured between participants. Reaction times and number of correctly recalled words were recorded.

Apparatus. The experiment was presented on Superlab version 4.0.7b running on Macbook Air with an Intel Core i5 processor (1.7GHz) using OS X Yosemite. Stimuli were displayed on a 11" flat screen monitor at a resolution of 1366x768px.

Stimuli. Forty-five words were used with fifteen assigned to each condition. Words were rotated between conditions for each participant. Stimuli in the congruent and incongruent conditions were manipulated in terms of colour, global shape, individual letter orientation, font and spatial distribution of letters to achieve a picture like character for each stimulus that would either be representational of the meaning of the word (congruent condition) or irrelevant to the specific stimulus (incongruent condition). Different shapes were used in the incongruent condition to avoid exposing participants to the same featural manipulation more than once and thus avoid cross-condition cueing of individual stimuli. Examples of stimuli are shown in Figure 4.1 below.

Figure 4.1: Examples of stimuli used. From left to right: congruent, incongruent, control.

Procedure. Participants provided demographic data and consent in writing before starting the experiment. They then completed the experiment individually on a computer. All instructions were provided onscreen and they were given the opportunity to ask questions. In order to test incidental recall of stimuli, participants were given a distraction task. For each of the 45 trials, they were asked to decide whether or not the word referred to an animal. After completing the initial presentation phase of the experiment, participants were then presented with a surprise recall test and asked to write down as many of the items as they could remember on a separate piece of paper. Finally, participants were debriefed and given another opportunity to ask any questions.

Results

Two mixed measures 3x2 ANOVAs were run to assess the effect of presentation format and native language on reaction times and recall scores for native and non-native speakers. Descriptive statistics displaying means and standard deviations for both dependent variables can be seen in Table 4.1 below.

Table 4.1: Means and standard deviations of reaction times and recall scores for native and non-native speakers across presentation formats.

	reaction times	**recall scores**

		mean	SD	mean	SD
congruent	native speakers	3185.74	2077.4	2	1.71
	non-native speakers	3831.22	1957.38	1.94	1.47
incongruent	native speakers	3136.78	1594.97	2.19	1.71
	non-native speakers	3445.81	2040.67	1.94	1.39
control	native speakers	1541.62	524.67	2.44	1.87
	non-native speakers	1659.1	764.7	1.89	1.49

In order to assess the validity of the data, an additional, preliminary, mixed measures ANOVA was run on correct identification scores for whether a word did or did not refer to an animal. A t-test was also carried out to assess the likelihood of recalling animals in comparison to recalling other target items during free recall. The results of the preliminary ANOVA are shown in Figure 4.2 below.

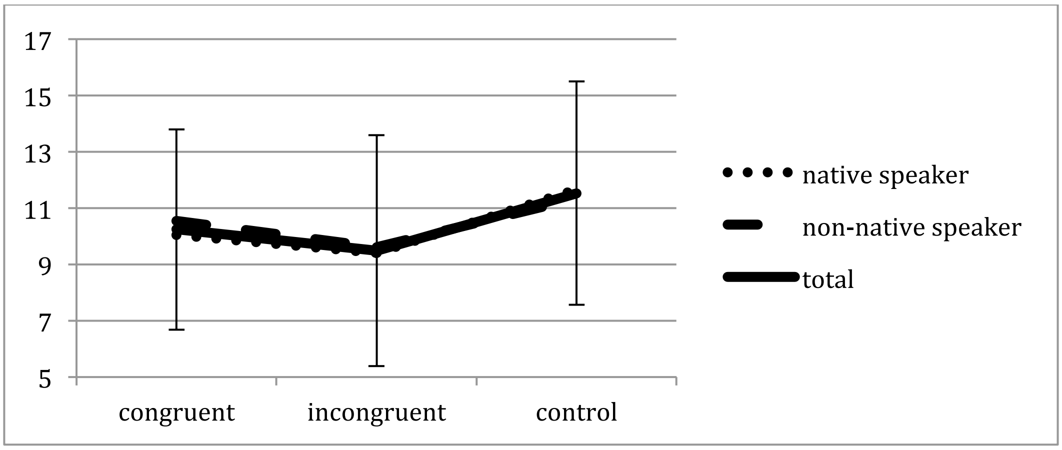

Figure 4.2: Means and standard deviation for number of correctly identified animals across presentation formats for native and non-native speakers

When analysing error rates for animal identification across conditions a significant main effect of presentation format was found, $F(2, 86)=10.026$, $p<0.001$, $\eta_p^2=0.189$. No significant main effect was detected for native language, $F(1, 43)<1$, p=0.905, η_p^2 <0.001. No significant interaction between presentation format and native language was found, F(1, 86)<1, p=0.631, η_p^2 <0.011. Simple effects using Bonferroni post-hoc analysis revealed that stimuli in the control condition differed significantly from both congruent (p=0.005) and incongruent stimuli (p=0.001). No differences were observed between congruent and incongruent stimuli (p=0.336), with lower error rates observed for control stimuli. Repeated measures t-tests showed that overall more animals than other words were recalled, t(44)=1.896, p=0.064. When conditions were assessed separately, it became clear that the difference arose from control stimuli only, t(44)=2.389, p=0.021, while no differences were observed for either congruent, t(44)=-0.558, p=0.580, or incongruent words, t(44)=1.032, p=0.308.

Reaction times. For reaction times, a significant main effect of presentation format was found, F(2, 86)=27.924, p<0.001, η_p^2 =0.394. No significant main effect was found for native language, F(1, 43)<1, p=0.334, η_p^2 =0.022. No significant interaction was found between presentation format and native language, F(2, 86)<1, p=0.503, η_p^2 =0.011. Simple effects from a Bonferroni post-hoc test revealed that control stimuli were recognised faster than both congruent (p<0.001) and incongruent (p<0.001) stimuli. No difference was observed between congruent and incongruent stimuli (p=1). Findings are shown in Figure 4.3 below.

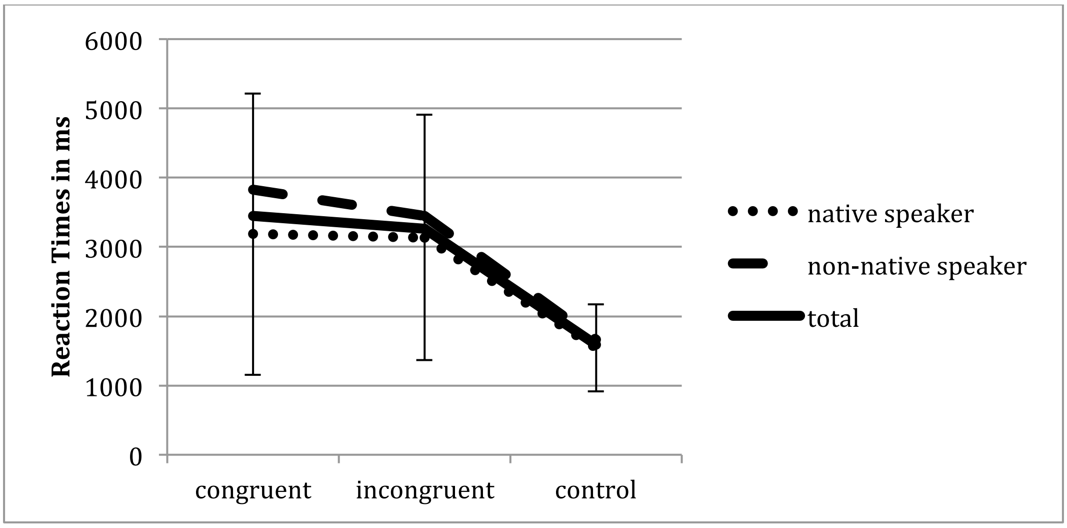

Figure 4.3: Means and standard deviations of reaction times for stimuli across presentation formats

Recall scores. When looking at recall scores no significant effect was found for either presentation format, $F(2, 86)<1$, $p=0.851$, $\eta_p^2=0.004$, or native language, $F(1, 43)<1$, $p=0.362$, $\eta_p^2=0.019$. No significant interaction was found between presentation format and native language, $F(2, 86)<1$, $p=0.762$, $\eta_p^2=0.006$. The findings are presented in Figure 4.4 below.

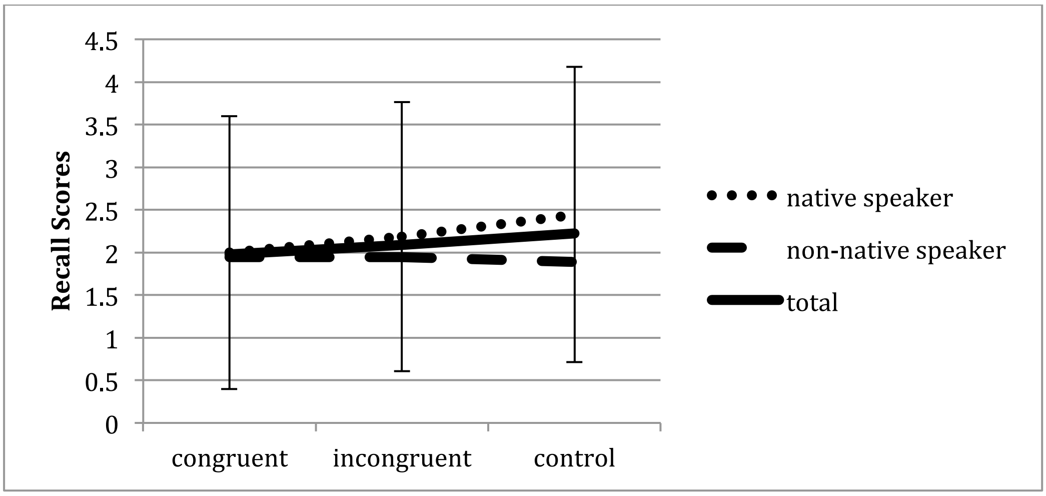

Figure 4.4: Means and standard deviations of recall scores for stimuli across presentation formats

Effect of Exposure Time. Due to the significant differences in exposure time between the types of stimuli, correlations were run to investigate the impact of exposure time on recall. No significant correlations between exposure time and recall scores were observed for any of the presentation formats.

Table 4.2: Correlations between reaction times and recall scores for the three presentation formats.

Presentation format	**r**	**p**
congruent	-0.093	0.544
incongruent	0.128	0.400
control	-0.183	0.228

Discussion

Experiment 5 was designed to examine the impact of dimension congruency in integrated stimuli, encompassing both verbal and non-verbal information, while using more complex stimuli. Under these conditions, no effect of congruence was observed for either reaction times or recall scores. Reaction times did suggest, however, that as in previous experiments, integrated stimuli took longer to process than control items. As previously discussed in greater detail, this is likely to be a cumulative effect of both greater reading practice and familiarity with standard font words (Hommel et al., 2004) and increased processing demands for integrated items (Maisto & Queen, 1992). No differences in overall recall were observed between integrated and control stimuli, suggesting that the combination of verbal and non-verbal information neither helped nor hindered item recall in this instance. No effect was observed for native language in this experiment. Although participants were made aware that their response times were recorded and asked to answer as fast and accurately as possible, overall response times were still unusually long. Reading times for words have usually been found to range between 300ms and 400ms (Just, Carpenter & Woolley, 1982). Categorisation can be achieved in the same range (VanRullen & Thorpe, 2001) but may take as long as 1000ms (Schnyer, Dobbins, Nicholls, Davis, Verfaellie, & Schacter, 2007).

It is possible that participants may not have prioritised speed, resulting in a speed-accuracy trade off. It is equally possible that as a result of the mixed list design, participants were still processing more demanding stimuli seen in a previous block, therefore slowing down responses overall. Since reaction times did not shorten even with clear instructions and having ensured participants' awareness that response speed was assessed, future experiments will use pre-timed trials, with equal exposure for all stimuli. This will also help to categorically exclude any confounding impact of stimulus exposure on recall (McDaniel & Einstein, 1986).

The findings mirror those of Experiment 1. As in Experiment 1, no effect of exposure time on recall was observed for any of the types of stimuli, suggesting that task instructions once more had a substantial effect on how participants processed stimuli in the experiment (Noldy et al., 1990). Interestingly though, while a greater number of animals were recalled in the control condition, no such difference was observed for either type of integrated stimuli. While no difference was found for the overall number of words recalled for each presentation format, the variation in the number of animals recalled suggests that while task instructions impacted significantly on how control words were encoded and subsequently recalled, the same encoding mechanisms were not applied to integrated stimuli. This adds to the growing evidence that encoding processes for integrated items differ in a variety of ways from standard font words and suggest they may be less likely to be affected by external factors including task demands and exposure time. Similar findings have been obtained by Einstein, McDaniel and Lackey (1989) who reported that bizarre stimuli were less prone to task interference than common items. Nevertheless, a negative impact of encoding strategy cannot be excluded on the basis of the current findings and Experiment 6 will replicate the current experiment using pre-timed trials to ensure fixed exposure times, while omitting the categorisation task.

Experiment 6

Experiment 5 revealed further potential processing differences between integrated and control stimuli. Following a categorisation task, more animals were recalled for control items than integrated stimuli. Yet, no effect of congruency was observed for incidental recall scores. As previously observed in Experiment 1, this lack of an effect may be a result of the task requirements (Noldy et al., 1990), with participants focussing on identifying animals rather than committing any of the items to memory. Results may suggest that categorisation does not lend itself to increasing item memorability. This level of semantic decision-making would also be considered a more shallow level of processing activating only superficial information about each item, rather than deep conceptual activation, therefore leading to a weaker memory trace for these stimuli (Craik & Lockhart, 1972).

Although no correlations were found between reaction time and recall for Experiment 5, this cannot entirely exclude the possibility of an attentional hypothesis as a confounding factor (McDaniel & Einstein, 1986). Furthermore, response latencies were unusually long (VanRullen & Thorpe, 2001; Schnyer et al., 2007) and further investigation may prove to be of little benefit and yield no informative conclusions. Therefore, Experiment 6 made use of the same conditions and stimuli as Experiment 5, but exposure time was fixed to 2000ms per trial. The fixed response time also eliminated the need for a participant response to move to the next trial, consequently allowing the categorisation task to be omitted. Participants were instructed to simply read words without taking any further action. They remained unaware of the memory test, although it cannot be excluded that they may have anticipated a recall test.

It is expected that results will mirror those of Experiment 5, with the restriction of processing time exerting no negative impact on word comprehension (McDaniel & Einstein, 1986; Bugelski & Rickwood, 1963). It is further expected that a more pronounced recall pattern may emerge, highlighting potential differences in processing depth between congruent, incongruent and control stimuli. In addition, the effect of native language may become more evident and benefits derived by native speakers from congruent stimuli may become more obvious in the absence of specific encoding instructions.

Methodology

Participants. A total of 45 undergraduate students participated in the experiment on a voluntary basis. Just over half the sample were male (24; 53.3%). Ages ranged from 18 to 54 with a mean age of 25.36 years (SD=6.93 years). Just over 60% of the sample (28) identified themselves as native speakers, while the remaining students spoke English as a second language. Approximately half of the sample was Black (51.1%), followed by Asian (31.1%), and White (20.6%). One participant identified as being of mixed ethnic heritage (2.2%).

Design. Congruency was manipulated as in Experiment 5 and native language was assessed between participants. Since exposure was timed to 2000ms per stimulus only the number of correctly recalled items was recorded.

Apparatus and Stimuli. The same apparatus and stimuli were used as in Experiment 5.

Procedure. Participants provided demographic data and consent in writing before starting the experiment. They then completed the experiment individually on a computer. As before, all instructions were provided onscreen and they were given the opportunity to ask questions. The same 45 stimuli were used as in Experiment 5, but exposure time was now restricted to 2000ms per trial and no response was required from participants. At the end of the presentation, participants were asked to write down as many of the items as they could remember on a separate piece of paper. Participants were then debriefed and given another opportunity to ask questions.

Results

A mixed measures 3x2 ANOVA was conducted to examine the effect of presentation format and native language on recall scores with a 2000ms exposure time. Descriptive statistics displaying means and standard deviations for recall scores can be seen in Table 4.3 below.

Table 4.3: Means and standard deviations of recall scores for native and non-native speakers across presentation formats.

		recall scores	
		mean	**SD**
congruent	native speakers	2.39	1.87
	non-native speakers	2	1.22
incongruent	native speakers	1.96	0.96
	non-native speakers	2.65	1.77

control	native speakers	2.75	2.55
	non-native speakers	2.76	1.52

No significant main effects were found for presentation format, $F(2, 86)=1.151$, $p=0.321$, $\eta_p^2=0.026$ or native language, $F(1, 43)<1$, $p=0.740$, $\eta_p^2=0.003$. No significant interaction between presentation format and native language was found, $F(2, 86)<1$, $p=0.387$, $\eta_p^2=0.022$. The findings are illustrated in Figure 4.5 below.

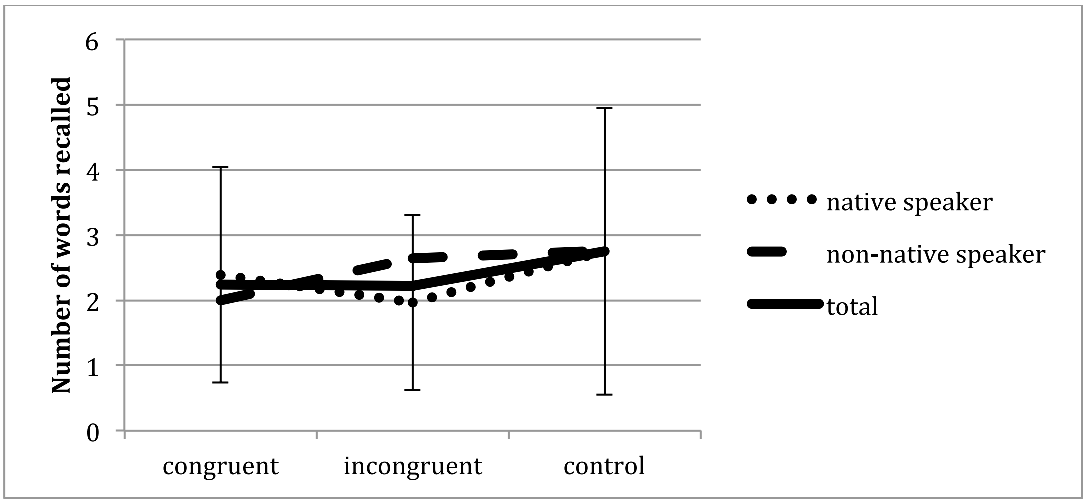

Figure 4.5: Means and standard deviations of recall scores for native and non-native speakers for all presentation formats.

Discussion

In Experiment 6 trials were pre-timed and fixed to a duration of 2000ms each in order to control for any potential impact of exposure time (McDaniel & Einstein, 1986). As in Experiment 5, no effect was found for either the presentation format or native language. As predicted, the data suggest that exposure time had little impact on accuracy of word processing and that items were equally well understood within a limit of 2000ms than when viewing time was determined by the participants' own pace. Recall was unaffected and recall scores did not reduce from Experiment 5 as a result of reduced exposure time. While no significant effects of congruence or native language were observed, native speakers did show a minutely higher score for congruent items than non-native speakers, with the opposite pattern observed for incongruent stimuli. Control words presented no differences based on native language. This may indicate a potential trend for native speakers to be able to utilise congruent features in a way uniquely linked to their language proficiency. Further investigation is needed to establish if this small trend has merit.

While the results obtained in the current experiment exclude the potential confounding impact of exposure time, they leave the impact of encoding conditions unclear. While participants did not perform any categorisation task in this experiment, recall was still poor overall with merely two to three words out of 15 recalled in each condition. This suggests that participants may not have anticipated a recall test after all and may not have made any effort to recall stimuli. It is highly likely that if participants were made aware of the recall test, their performance would increase substantially (Rüsseler, Hennighausen, Münte & Rösler, 2003; Noldy et al., 1990). It should furthermore be considered that while incidental encoding is more easily tested with a recognition task, intentional memory has been found to produce more accurate results in free recall tests (Eagle & Leiter, 1964). These particular concerns will be addressed in Experiments 7 and 8.

Experiment 7

While Experiment 5 revealed further potential processing differences between integrated and non-integrated stimuli, no effect of congruency was observed for incidental recall. Findings did suggest that a categorisation task had less impact on integrated than control stimuli, but overall recall rates were similar across presentation formats. Reaction times were once more found to be excessive and for Experiment 6 fixed trials were introduced. The results of Experiment 6 confirmed that the amount of exposure time plays only a limited role in comprehension accuracy and that participants on average took substantially more time to examine the stimuli than required for processing. Furthermore, restricting processing time had no negative impact on recall scores of integrated stimuli.

Eagle and Leiter (1964) suggested that incidental encoding produces better retention scores for recognition, while intentional encoding is more accurately measured through free recall. The use of incidental encoding up to this point can also account for the overall low recall scores with a mean recall rate below 20% for all conditions. In order to address these issues, instructions were altered to make participants aware of the upcoming memory test, while exposure time remained at 2000ms per trial.

It is expected that recall scores will increase for all presentation formats as a result of the altered task instructions, forewarning participants to remember as many of the presented stimuli as possible and effectively switching encoding mechanisms from incidental to intentional. It is furthermore expected that congruency will show a more pronounced effect for intentionally encoded material (Rüsseler et al., 2003; Noldy et al., 1990) and that differences between native and non-native speakers will emerge more clearly, potentially highlighting an interaction effect between congruence and native language as a result of more effective processing of congruent information by native speakers (da Costa Pinto, 1991).

Methodology

Participants. A total of 45 undergraduate students participated in the experiment on a voluntary basis. The majority of respondents were female (27; 60%). Ages ranged from 18 to 42 with a mean age of 21.84 years (SD=3.97 years). Sixty per cent of the sample (27) identified themselves as native speakers, while the remaining students spoke English as a second language. The majority of the sample was Asian (44.4%), followed by White (28.9%) and Asian (24.4%). One participant reported other ethnic origins (2.2%).

Design. Congruency was manipulated as in Experiment 5 and 6. Native language was assessed between participants. Since exposure was again pre-timed at 2000ms per stimulus only the number of correctly recalled items was recorded.

Apparatus and Stimuli. The same apparatus and stimuli were used as in Experiments 5 and 6.

Procedure. Participants provided demographic data and consent in writing before starting the experiment. They then completed the experiment individually on a computer. As before, all instructions were provided onscreen and they were given the opportunity to ask questions. The same 45 stimuli were used as in Experiment 5, but participants were now instructed to remember as many of the items as possible. In addition, exposure time was now restricted to 2000ms per trial and no response was required from participants. At the end of the presentation, participants were asked to write down as many of the items as they could remember on a separate piece of paper. Participants were then debriefed and given another opportunity to ask any questions.

Results

A mixed measures 3x2 ANOVA was conducted to examine the effect of presentation format and native language on recall scores with a 2000ms exposure time. Descriptive statistics displaying means and standard deviations for recall scores can be seen in Table 4.4 below.

Table 4.4: Means and standard deviations of recall scores for native and non-native speakers across presentation formats.

		recall scores	
		mean	**SD**
congruent	native speakers	3.59	3.09
	non-native speakers	2.22	1.77
incongruent	native speakers	1.93	1
	non-native speakers	2.56	2.15
control	native speakers	3.59	1.6
	non-native speakers	4.72	2.56

A significant main effect of presentation format was found, $F(2, 86)=10.040$, $p<0.001$, $\eta_p^2=0.189$. No significant main effect was found for native language, $F(1, 43)<1$, $p=0.753$, $\eta_p^2=0.002$. A significant interaction between presentation format and native language was also found, $F(2, 86)=4.640$, $p=0.012$, $\eta_p^2=0.097$.

Simple effects obtained through Bonferroni post-hoc analysis revealed that recall was higher for control words than incongruent stimuli ($p<0.001$). Control words were also more likely to be recalled than congruent stimuli, but the difference fell short of statistical significance ($p=0.067$). No difference was found between recall for congruent and incongruent stimuli ($p=0.453$). Simple interaction effects further revealed a tendency for non-native speakers to recall more control words than native speakers, while native speakers showed higher recall for congruent words compared to non-native speakers. Both differences fell short of statistical significance, p=0.075 and p=0.096 respectively. No difference was observed for incongruent words (p=0.191). The findings are illustrated in Figure 4.6 below.

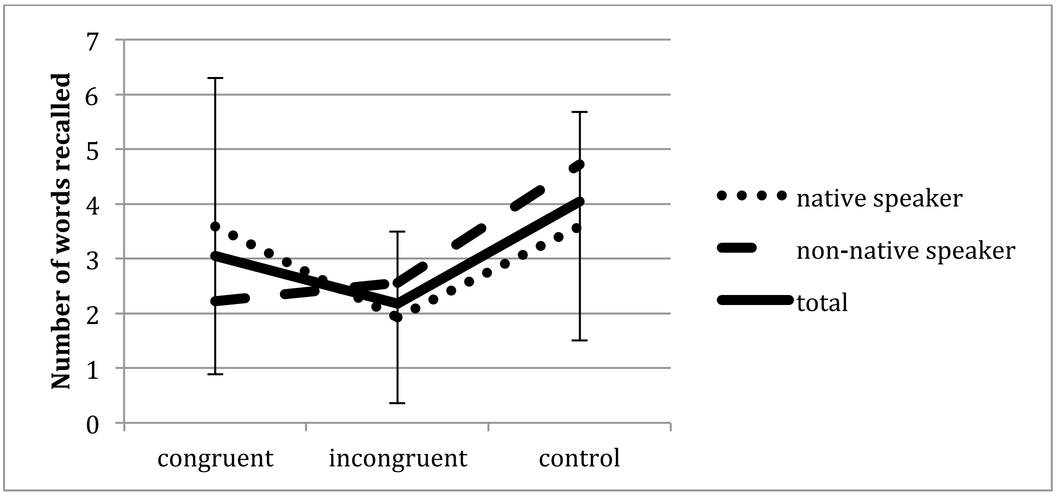

Figure 4.6: Interaction of congruency and native language for number of correctly recalled items; means and standard deviations

Due to the distinct patterns observed for native and non-native speakers, the analysis was repeated, omitting non-native speakers from the sample. A significant effect of presentation format was observed, F(2, 52)=5.786, p=0.005, η_p^2 =0.182. Bonferroni post-hoc analysis showed that incongruent stimuli were significantly less likely to be recalled than both congruent (p=0.033) and control stimuli (p<0.001). No difference was observed between congruent and control words (p=1).

Discussion

Experiment 7 altered encoding strategy from incidental to intentional encoding. The reason for this was twofold. Switching to intentional encoding was expected to both raise overall recall rates, thus potentially amplifying any differences between presentation formats. In addition, Eagle and Leiter (1964) suggested that intentional encoding was more suited to a free recall test than incidental encoding, and provided a more reliable measure of retention. Since restricting reaction times had no detrimental impact on recall in Experiment 6 and response latencies have not been as informative as desired in previous experiments, each trial was fixed to a duration of 2000ms.

Recall scores showed a significant effect of presentation format with highest recall scores observed for control stimuli, producing significantly higher recall rates than incongruent words. Recall for control words was also higher than recall for congruent words, but this difference was non-significant. The results show that altering encoding from incidental to intentional, had a substantial impact on recall, producing higher mean recall scores for both control and congruent stimuli, while leaving incongruent stimuli unaffected. Although participants were now aware that they would be tested on the items presented, they were unable to improve retention of incongruent words. They were, however, successful in improving retention for both congruent and control stimuli. This suggests that both control stimuli and stimuli containing congruent, integrated information can be successfully encoded and recalled under suitable conditions, while this process is substantially less efficient for incongruent, integrated information. This underlines the importance of meaningfully integrated information (Garner, 1976) as opposed to stimuli that simply attract attention through novelty or bizarreness (Merry, 1980). In addition, native speakers were found to derive greater benefit from integrated stimuli than non-native speakers, and showed no differences in retention scores for congruent and control words. The reverse pattern was observed for control words. This strongly suggests that integration of meaningfully related verbal and non-verbal information is more readily processed by native speakers for whom this association is significantly stronger as a result of greater language proficiency and life-long exaposure (da Costa Pinto, 1991). This is further supported by the lack of an observed difference between native and non-native speakers for incongruent stimuli, where no meaningful integration can be achieved to enhance memorability. Despite the observed increase for control and congruent words, recall rates remained low (Standing, 1973) with the highest recall mean below 30%. In an effort to increase recall rates, exposure times were extended in Experiment 8.

Experiment 8

Results from Experiment 7 showed a clear advantage for using intentional instead of incidental encoding instructions. Recall scores increased for both congruent and control stimuli, but did not change for incongruent items. Despite this observed increase, overall recall was still low. Experiment 8 aimed to increase recall by extending exposure time. Since processing times were on average just below 3500ms for congruent and incongruent stimuli in Experiment 5, where trial length was participant-paced, Experiment 8 replicated the design of Experiment 7, but extended exposure time to 4000ms per trial to ensure that all stimuli could be fully processed. It is expected that congruent stimuli and control stimuli will derive greater benefit from longer exposure and that retention will improve for both types of items. Control words may benefit more from increased rehearsal time (Cook, Wright & Sands, 1991; Memon, Hope & Bull, 2003), since processing for these items is expected to be faster than for integrated items (VanRullen & Thorpe, 2001). With the provision of additional rehearsal time some improvement is also expected for incongruent stimuli. As a result of extended exposure, participants will have the opportunity to separate irrelevant physical features from relevant verbal information, which may increase recall likelihood.

Methodology

Participants. A total of 45 undergraduate students participated in the experiment on a voluntary basis. Just over half of the respondents were female (23; 51.1%). Ages ranged from 18 to 58 with a mean age of 22.91 years (SD=5.97 years). Approximately, sixty per cent of the sample (26) identified themselves as native speakers, while the remaining students spoke English as a second language. The majority of the sample was Asian (51.1%), followed by Black (26.7%), White (17.8%) and mixed ethnic heritage (2.2%). One participant reported other ethnic origins (2.2%).

Design. The design was the same as in Experiment 6, but exposure time was set to 4000ms per stimulus. The number of correctly recalled items was recorded.

Apparatus and Stimuli. The same apparatus and stimuli were used as in Experiment 5, 6 and 7.

Procedure. Experiment 8 replicated Experiment 7, but exposure time was extended from 2000ms to 4000ms per trial. Participants were once again instructed to actively try to remember as many of the items as possible.

Results

A mixed measures 3x2 ANOVA was conducted to examine the effect of presentation format and native language on recall scores with a four second exposure time. Descriptive statistics displaying means and standard deviations for recall scores can be seen in Table 4.5 below.

Table 4.5: Means and standard deviations of recall scores for native and non-native speakers across presentation formats.

		recall scores	
		mean	**SD**
congruent	native speakers	4.15	2.81
	non-native speakers	3	1.76
incongruent	native speakers	2.92	1.72
	non-native speakers	3.26	1.94
control	native speakers	3.96	1.95
	non-native speakers	4.63	2.29

A significant main effect of presentation format was found, F(2, 86)=4.372, p=0.016, η_p^2 =0.092. No significant main effect was detected for native language, F(1, 43)<1, p=0.913, η_p^2 <0.001. The interaction between presentation format and native language fell just short of significance, F(2, 86)=2.816, p=0.065, η_p^2 =0.061.

Bonferroni post-hoc analysis for simple effects revealed that control words were significantly more likely to be recalled than incongruent stimuli (p=0.008) but did not differ from congruent stimuli (p=0.371). Congruent and incongruent stimuli showed no difference (p=0.653). Once again, congruent items were more likely to be recalled by native speakers while control words produced higher recalls scores for non-native speakers. However, neither of those differences were found to be significant, p=0.123 and p=0.296 respectively. The findings are shown in Figure 4.7 below.

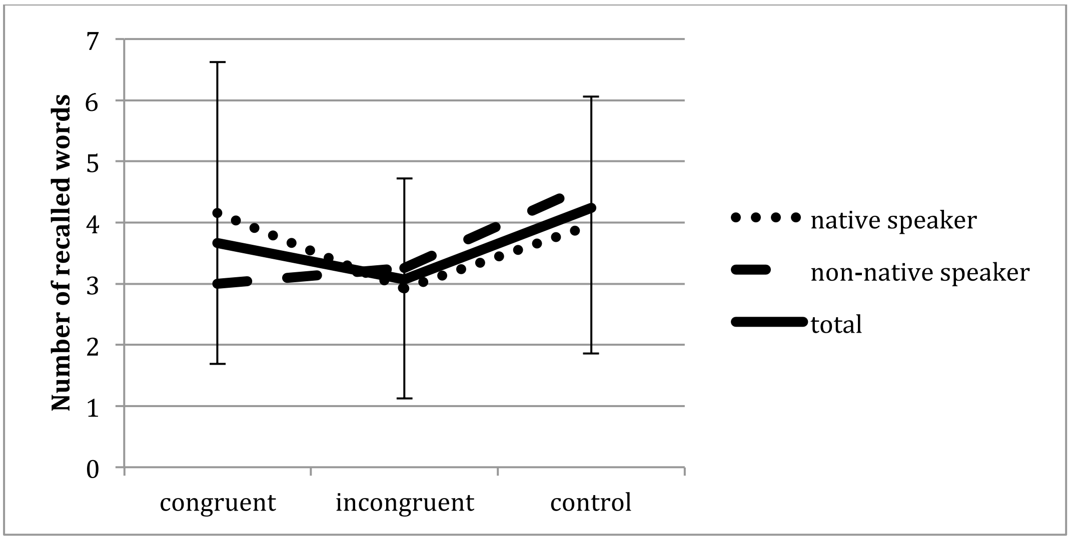

Figure 4.7: Means and standard deviations for number of correctly recalled items for all presentation formats for native and non-native speakers

As for Experiment 7, non-native speakers were once more omitted from the analysis before re-running the ANOVA. The effect of presentation format fell short of significance, F(2, 50)=2.624, p=0.083, η_p^2 =0.095.

Discussion

Experiment 8 replicated Experiment 7 but extended exposure time from 2000ms to 4000ms per trial. This adaptation was made in an effort to increase recall rates overall and ensure that both verbal and non-verbal information contained in integrated stimuli could be fully processed. Results obtained from Experiment 8 mirrored those obtained in Experiment 7. A further increase in recall scores was observed for both congruent and control items, although the increase was relatively small with only one additional word recalled on average. As before, control words were remembered better than incongruent words, but extended exposure times eliminated any difference between congruent and control words. Recall scores also increased for incongruent stimuli, which once more did not differ significantly from congruent items, but still displayed lowest recall scores compared to the other two presentation formats. This emphasises the importance of a meaningful connection between the verbal and non-verbal material (Garner, 1976) as opposed to simply using bizarre imagery to instil memorability (Merry, 1980). As in Experiment 7, native speakers showed better recall for congruent words, while non-native speakers performed better when recalling control words. As in previous experiments no superior recall was observed for congruent stimuli compared to control items. A possible reason for this could be the amount of exposure allocated to each trial. It needs to be considered that while all presentation formats were given equal exposure time, it is unlikely that processing demands were equal across conditions. Control words shown in standard font are highly familiar and reading has been practiced throughout life and has likely become automatic as a result (Hasher & Zacks, 1979) making access to these items extremely fast and efficient (VanRullen & Thorpe, 2001). In contrast, integrated stimuli are presented in a highly unfamiliar format and required processing time is likely to increase substantially as a result (van Leeuwen & Lachmann, 2004; Maisto & Queen, 1992; Ahlén, Hills, Hanif, Rubino & Barton, 2014). Consequently, an equal amount of exposure time is unlikely to be equally beneficial to both control and integrated stimuli and control stimuli likely received substantially more rehearsal than integrated items. If basic access time for congruent and incongruent stimuli could be reliably determined, increased rehearsal time could then be meaningfully extended for all presentation formats as multiples of basic processing time rather than the same absolute value for all.

When scores for native speakers were analysed separately, no effect of presentation format was found at longer exposure. The lack of a difference between congruent and control stimuli, as discussed above, may arise from the imbalance between time needed for initial processing and time available for rehearsal during exposure. The lack of a difference in comparison to incongruent stimuli may indicate that native speakers could be both more adept at using congruent information to aid memory as well as suppressing irrelevant incongruent information in favour of retaining core detail.

General Discussion

Data presented in Chapter 2 showed that recall for integrated stimuli was less susceptible to the impact of exposure time. This suggested that integrated information is not processed in the same way as words printed in regular font, since exposure time has been commonly identified as a determining factor in recall likelihood (Loftus & Kallman, 1979; Potter & Levy, 1969; Tversky & Sherman, 1975). Similar results have been observed for location recall accuracy of salient compared to common stimuli in a visual display. Fine and Minnery (2009) reported that location of salient stimuli was recalled more accurately although no difference in eye fixation time was observed, suggesting that mere allocation of attention to relevant locations could not account for the effect. Subsequently, experiments presented in Chapter 3 demonstrated the importance of dimension congruency of integrated verbal and non-verbal information for successful processing to occur. Chapter 3 also confirmed the successful integration of verbal and non-verbal information into a single object as indicated by a lack of effect when altering control settings between the two dimensions for integrated stimuli. Data presented in the current chapter further underlined both these findings, with a clear difference observed in the effect of task demands on recall, supporting the notion of different encoding processes being used for integrated stimuli. In addition, the importance of feature congruence was confirmed. While congruent words did not differ from control stimuli, incongruent stimuli produced significantly lower recall scores, suggesting that the novel format alone did not lead to improved retention of the material (Kroll, Schepeler & Angin, 1986).

The four experiments presented here were designed to assess the impact of congruence on dimensional integration of verbal and non-verbal information under both incidental and intentional encoding conditions. Experiment 5, which tested incidental recall by use of a categorisation task, offered further evidence that integrated items are subject to different processing mechanisms than regular font words and that they are less susceptible to the influence of task demands. This may be an effect of the stimuli's salience compared to control words, which has been previously observed by Einstein et al. (1989). Experiments 6 reliably eliminated an influence of processing time by limiting trials to 2000ms each. Recall scores were not negatively affected for any of the presentation formats and recall for congruent and control stimuli increased as a result of eliminating the distractor task. Experiment 7 and 8 in turn highlighted the importance of encoding instructions, altering the design from incidental to intentional recall. Experiment 7 yielded improved recall for both congruent and control stimuli after making participants aware of the recall test. Results furthermore confirmed the importance of meaningful integration of information (Garner, 1976) as well as the greater benefit gained by native over non-native speakers (da Costa Pinto, 1991) from providing integrated dual route access.

The findings confirm both the potential confounding effect of task instructions on memory of bizarre items (Einstein et al., 1989) as well as the diminished impact of exposure time on recall of salient stimuli (Fine & Minnery, 2009; Gounden & Nicolas, 2012). Neither restricting nor extending exposure time showed a substantial impact on processing on integrated items. These results add to the growing evidence suggesting that different processing mechanisms are involved in the encoding of integrated stimuli. Furthermore the results highlight the importance of encoding conditions and the distinct pattern of results obtained for incidental compared to intentional encoding. Switching encoding instructions substantially improved performance, particularly for congruent items in native speakers. Findings overall indicate significantly greater benefits of congruence derived by native speakers. It is clear from the data that native speakers processed congruent, integrated information more effectively and used it to their advantage achieving both faster processing and better recall than non-native speakers. In contrast, non-native speakers consistently performed better for incongruent than congruent stimuli. This may suggest that there is greater mental effort involved for non-native speakers when connecting verbal labels of their second language to stored conceptual information, which will always be most closely associated with L1 descriptors. Conversely, incongruent information could be less of a hindrance for non-native speakers, as they will experience less interference since their conceptual knowledge is less strongly linked to the verbal descriptors in their second language (da Costa Pinto, 1991).

While the experiments described in this chapter would not be regarded as Stroop tests in the traditional sense, results show some common ground with previous Stroop studies. No differences in processing speed between congruent and incongruent stimuli were observed in Experiment 5, however, this is likely a result of the long response latencies, resulting in small speed deviations going unnoticed. Notably though, when exposure was pre-timed congruent items yielded better recall than incongruent items, particularly under intentional encoding conditions and for native speakers. This may suggest that congruent items were processed more efficiently and more fully during the time available. This interpretation is compatible with Stroop data as well as the underlying assumptions regarding the effect of dimensional congruence. Compatible information is more easily integrated leading to faster processing, higher response accuracy and in the current experiments, increased recall rates. In turn, incongruent items cannot benefit from this mechanism, meaning that information is poorly processed and not readily integrated into an existing mental framework due to the incompatibility of presented cues. Additional effort would also need to be exerted to separate the relevant from the irrelevant information. In addition, following the experiments some participants spontaneously reported being able to recall a shape but not the verbal content of an item. While this could occur for both types of integrated stimuli, it may suggest that for incongruent items the irrelevant information could be a potential source of interference at recall and may prevent verbal information from being recalled since no link can be established between the two. In contrast, retaining the shape of congruent items carries a high likelihood of cueing verbal information since features are designed to resemble the object in question.

The results suggest that conceptual processing as a result of feature integration was successful and that given sufficient processing time to allow for the added cognitive load (Noldy et al., 1990), integrated stimuli are recalled on par with standard font words and may even outperform them if rehearsal time is proportionally extended. While exposure time has been found to have no impact on recall of unusual or bizarre material (Gounden & Nicolas, 2012), additional processing time may be needed for more complex items (Kline & Groninger, 1991). As discussed earlier, processing demands are likely to be higher for integrated stimuli, although practice may serve to eliminate this effect to an extent (Ahlén et al., 2014). Nevertheless, it is unlikely that even with extensive practice, processing speeds comparable to standard text could be achieved within the scope of an experimental setting. The results further suggest that conceptual processing occurs more readily for congruent than incongruent stimuli. This is likely a result of relevant semantic activation, leading to increased imagery and improved recall (Paivio, 1976; Sadoski, 1985).

The data also provide some insight into the relative impact of verbal and non-verbal information used during item retrieval. Pictures have been found to lead to better performance in free recall tasks (Paivio & Csapo, 1973; Cohen, 1973), outperforming words on both intentional and incidental encoding designs (Noldy et al., 1990). The lack of an observed difference between congruent and control stimuli, suggests that items were processed mostly on a verbal level, lending support to the notion that verbal information is largely processed on an automatic level (Noldy et al., 1990; Stroop, 1935). However, results presented in Chapter 2 regarding the absence of an effect of prolonged exposure, suggest that the non-verbal dimension also exerts substantial influence over encoding strategy, with pictures having been found to be less vulnerable to manipulation of exposure time than words (Cohen, 1973). It has been suggested repeatedly that presenting both verbal and non-verbal information relating to the same concept will have an additive effect on memory and that both dimensions separately enrich the memory trace (Paivio & Csapo, 1973; Paivio & Desrocher, 1980; Paivio, 1991). Similarly, it cannot be excluded that verbal information was extracted from integrated stimuli and processed with a degree of automaticity, focusing on the familiar format, while non-verbal information could have acted mostly as a distractor, hindering effective processing and thus slowing encoding, while failing to enhance recall.

The current chapter presented four experiments, investigating free recall performance for both incidental and intentional encoding instructions. While intentional encoding has been found to be beneficial for free recall performance, incidental recall is more efficiently tested using a recognition paradigm (Eagle & Leiter, 1964). Encoding strategies clearly vary between incidental and intentional processing of stimuli. Research has suggested that while focusing on individual item features benefits recognition, successful recall is more readily achieved when overarching links can be drawn between items within the to be recalled set, which is likely to increase inter-item cueing (Tversky, 1973). This effect was certainly observed to an extent for control stimuli in Experiment 5, where more animals were recalled when a sorting task asked participants to distinguish between animals and non-animals. This may have allowed participants to group animals together and encouraged intra-category cueing. Some commonly observed memory effects can also be affected by encoding strategy and may be diluted or even eliminated (Nicolas & Marchal, 1998).

In sum, findings from the current chapter emphasise the role of encoding instructions. Results show that for intentional encoding, congruent integrated items perform as well as control items and can be successfully accessed even with limited exposure time. While this chapter offers some insight into the effects of encoding strategy, incidental and intentional recall strategies are not investigated in a direct comparison. Equally, altering recall strategy to a recognition task may offer a more comprehensible understanding of the extent to which integrated stimuli are encoded incidentally (Eagle & Leiter, 1964). These issues will be addressed in Chapter 5.

CHAPTER 5

Integrating Pictures and Words: Directed Forgetting in Recall and Recognition

Abstract

Findings obtained in the previous chapter revealed that integrated, congruent stimuli performed better under intentional than incidental encoding conditions and benefitted from extended exposure time. This suggests that when a recall test is expected participants find it easier to memorise integrated stimuli compared to standard words. Results therefore indicate that integrated items could be more suited to effective encoding strategies, significantly increasing likelihood of retention and retrieval in intentional recall. However, earlier research (Eagle & Leiter, 1964) has shown that incidentally encoded information may be better assessed using a recognition test as opposed to a free recall test. Consequently, the current chapter compared integrated and control stimuli using a directed forgetting approach, where participants are instructed to remember half the stimuli while forgetting the other half. This enabled direct comparison between intentionally and incidentally encoded stimuli. Experiment 9 examined retention using a free recall test, while Experiment 10 employed a recognition test. Results revealed that while integrated and control stimuli were recalled with equal accuracy, with to be remembered items producing significantly higher recall than to be forgotten items for both presentation formats, integrated

stimuli produced significantly higher recognition scores for both intentional and incidental encoding conditions. Recognition time did not differ as a result of presentation format or encoding cue. A final experiment addressed the respective role of verbal and non-verbal information during recognition. Findings were indicative of primarily verbal processing. Potential explanations are discussed.

Introduction

Results obtained in previous chapters showed that integrated stimuli were less prone to the effect of task demands, such as encoding instructions or exposure time and that both verbal and non-verbal information could be encoded successfully into a single stimulus under conditions of feature congruency. Experiments 5 and 6 showed that integration of congruent features appears to be of no benefit under incidental encoding conditions, where participants are unaware that they will subsequently be tested on item recall. When made aware of the recall test participants benefit significantly from using integrated, congruent information to aid recall, native speakers in particular deriving greater gain. While extended exposure did little to increase this observed advantage, it did result in higher recall for incongruent words, allowing them to compete for statistically equal recall scores with congruent and control items.

The principal aim of the present chapter was to examine whether integrated stimuli are affected by encoding manipulation when intentional and incidental recall conditions are run in a repeated measures design as well as to determine the impact of retrieval conditions. This was investigated in a directed forgetting paradigm where participants are explicitly instructed to only recall half the stimuli, while instructed to forget the other half. The chapter also explores the effects of retention test on performance, comparing recall and recognition, which have been found to test different types of memory (Eagle & Leiter, 1964). The final experiment was designed to directly explore whether verbal or non-verbal information plays a more prominent role in the processing of integrated stimuli.

Directed Forgetting

Bjork (1970) first discussed the idea of directed forgetting, theorising that if people were able to pool their mental resources in order to remember specific information, they ought to be equally able to forget information classed as irrelevant. While it is notoriously difficult to not think of certain stimuli such as a pink elephant – or a white bear – once it has been openly mentioned (Wegner, Schneider, Carter & White, 1987), people do indeed filter incoming information on a daily basis, retaining what is relevant and purging the rest from memory. This usually happens automatically and passively, without any effort being applied by the individual. If one was to remember every face encountered in the street and every conversation overheard on a train, this would put tremendous, unnecessary strain on mental resources and most of the retained information would likely be of no use in the future. This type of forgetting commonly results from a lack of encoding, rather than conscious forgetting of already encoded material. When attempting to channel the human ability to forget on purpose Bjork (1970) found that people were indeed very efficient in choosing to remember one set of information, but not another. When shown two lists of words and asked to remember only one of them, participants were highly successful in retrieving items from the to be remembered list while failing to recall items from the to be forgotten list. Later research has suggested that this process of forgetting may be more effortful than recalling information, perhaps as a consequence of the unusual request (Fawcett & Taylor, 2008). Distinct patterns of brain activation have also been reported for intentional remembering, intentional forgetting and unintentional forgetting (Wylie, Foxe & Taylor, 2008), supporting the idea that different mental processes are involved in these activities.

Initially, directed forgetting was tested through the list method (Geiselman, Bjork & Fishman, 1983; McNally, Clancy, Barrett & Parker, 2004), where participants are shown two separate lists of items. After viewing the first list, participants are informed that these items are for practice only and no longer need to be recalled. Subsequently, participants see a second list of items, following which they are asked to recall items from either list. Recall has consistently been shown to be higher for the to be remembered than to be forgotten list.

In later years, the item method (MacLeod, 1989; Paller, 1990) was developed where remember (R) or forget (F) instructions would be presented following each trial, rather than for a set of trials. Future studies concluded that there is little effect of whether the encoding cue (remember or forget instructions) is presented prior to, following (Weiner, 1968) or alongside stimulus presentation (Paller, 1990) and little effect of manipulating exposure time (Woodward & Bjork, 1971). In fact, item presentation time has varied widely from 1000ms (MacLeod, 1989) to 7000ms (Geiselman, 1975) without resulting in any alteration of the observed pattern of directed forgetting.

Further comparison between the list and item method revealed that while recall effects are observed for both experimental designs, only the item method produces a significant difference between R items and F items in recognition tests (MacLeod, 1999), while use of the list method results in equal recognition likelihood of R and F words (Elmes, Adams & Roediger, 1970; Block, 1971; Fawcett & Taylor, 2008). List length does not appear to affect this pattern (Sahakyan & Delaney, 2005). In addition, while participants could successfully identify the encoding cue received for items presented in the item method, cue retention was poor for the list method, where F items were identified at chance level (MacLeod, 1999; Bjork & Bjork, 2003).

A number of explanations for the occurrence of directed forgetting have been offered. In his initial paper, Bjork (1970) suggested that his data supported both a theory of set differentiation and selective rehearsal. The set differentiation explanation proposes that at encoding each item is tagged with either an R or F cue and thus entered into a distinct memory set, allowing targeted retrieval at retention test. A theory based on selective rehearsal suggests that based on the encoding cue more rehearsal time is allocated to R than F items, resulting in better retention for the former. Studies in support for both theories have been put forward (Reitman, Malin, Bjork & Higman, 1973; Epstein, Massaro, & Wilder, 1972 and Davis & Okada, 1971, respectively). Another explanation that has been presented is the inhibition hypothesis, which states that while both R items and F items are encoded into memory with equal efficiency, the F items are inhibited at the time of recall. While support has been offered for this theory (Wilson & Kipp, 1998; Fawcett & Taylor, 2008) it is weakened by findings showing that even when given a financial incentive to recall additional F items, participants are unable to do so (MacLeod, 1999). Conceivably, inhibition could occur on an unconscious level, with F items being actively suppressed rather than merely unattended during encoding. Sahakyan and Kelley (2002) have suggested that context change may also have a role to play in bringing about forgetting (also see Godden & Baddeley, 1975, for context dependent memory). While their findings support the theory, it is clearly more readily applied to the list than the item method, where both R and F items are encoded in the same context. Directed forgetting has been observed under both incidental (Nelson & Goodmon, 2003) and intentional (Smith & Vela, 2001) study conditions and its effect persists over a 1 to 2 week period, although recall declines for both R and F words over time (MacLeod, 1975).

Once the directed forgetting effect had been well established in the literature, research began to explore how it interacts with other known effects and under which conditions it can be reduced or eliminated. Initially, directed forgetting was tested in a levels of processing approach (Craik & Lockhard, 1972). Research found that while R words were affected in the familiar pattern of increased recall accuracy with deeper processing levels, F words showed no such effect and remained low across conditions (Wetzel, 1975). In addition, even at the most shallow processing level, R words significantly outperformed F words with the largest gap between the two noted on semantic processing trials (Horton & Petruk, 1980; also see Sahakyan & Delaney, 2003). While these experiments were unsuccessful in negating the effect of encoding instructions specifically aimed to reduce retention, other studies have found that more meaningful material, which by default is processed on a semantic level – such as sentences – significantly reduces the effect of directed forgetting (Geiselman, 1974). Furthermore, strong semantic relationships between target words from R and F conditions, such as closely adjacent category members, can lead to cueing during recall, thus undermining the effect of encoding strategy (Geiselman, 1977; Shebilske, Wilder & Epstein, 1971). The same was observed for strongly semantically related word pairs (e.g. seat – belt) when one word of each pair was supposed to be forgotten. This effect was shown to be particularly strong where the first word of the pair had to be recalled. In these trials, the second word was often retrieved regardless of instructions to forget (Golding, Long & MacLeod, 1994).

Although being largely unaffected by exposure time (Woodward & Bjork, 1971), stimuli under directed forgetting instructions are diluted by a number other known memory effects. A memory enhancing effect of emotional valence of stimuli has been observed in a number of studies for both words (Cahill, Prins, Weber &

McGaugh, 1994; Doerksen & Shimamura, 2001; Nagae & Moscovitch, 2002) and pictures (Bradley, Greenwald, Petry & Lang, 1992), and also persists in a levels of processing design (Ferré, 2003). Consistent with previous studies, emotionally arousing stimuli have also been found to be less affected by directed forgetting than neutral stimuli (DePrince & Freyd, 2001, but see Wessel & Merkelbach, 2006 for a contradictory account). Similar patterns of impact have been observed for self-referent memory (Rogers, Kuiper & Kirker, 1977; Kuiper & Rogers, 1979), the effect of various mental disorders (i.e. depression or anxiety; Hauswald & Kissler, 2008) and the impact of mental imagery (Bugelski, 1970).

Furthermore, in accordance with the picture superiority effect (Paivio & Csapo, 1973), directed forgetting has been found to be less pronounced in pictures than words. This phenomenon has been studied using pictures of animals (Basden & Basden, 1996), drawings of fruit, vehicles, body parts (Lehman, McKinley-Pace, Leonard, Thompson & Johns, 2001), and simple line drawing of everyday objects (Lehman, Morath, Franklin & Elbaz, 1998). The impact of forgetting cues is reduced further as picture complexity increases (Hauswald & Kissler, 2008).

Reaction times have only occasionally been recorded in directed forgetting (MacLeod, 1998). In studies that did examine reaction time, slowest and most accurate performance is usually observed for R words, with F items yielding faster response times but lower accuracy (Epstein, Wilder & Robertson, 1975; Howard, 1976), although other studies have reported slower response times for F words compared to R words (Fawcett & Taylor, 2008).

Recall versus Recognition

When assessing retention, it is commonly tested either through free recall or stimulus recognition (Kintsch, 1970; Karlsen & Snodgrass, 2004; Eagle & Leiter, 1964). Cued recall is also used frequently but will not be discussed further for the purpose of the present study. Research has repeatedly discovered conditions under which the type of retention test interacts with the material tested and as a consequence produces different results (Eagle & Leiter, 1964). Findings have shown that while high frequency words are more easily recalled, low frequency words are more readily recognised (Kintsch, 1970; Balota & Neely, 1980). The same pattern has been observed in relation to picture familiarity (Karlsen & Snodgrass, 2004). This may occur as a result of more frequent semantic node activation for high frequency words (Collins & Loftus, 1975), resulting in increased availability of these words in the mental dictionary, therefore making them easier to recall. On the other hand, low frequency items will experience much less frequent activation but as a result will benefit from being more distinctive than more commonly used words, making them easier to pick out at recognition (McDaniel & Einstein, 1986).

While overall recognition tests exhibit higher accuracy than recall tests (MacDougall, 1904), evidence has also suggests that the encoding mechanism used has a substantial effect on successful retention. Tversky (1973) argued that participants perform better if they are made aware which type of memory test they will be given (i.e. recall or recognition). Providing participants with specific encoding instructions suited to the retention test further improves performance. Tversky (1973) also found that recognition memory was enhanced by holistic item processing and detail integration leading to deeper semantic processing. In turn, recall performance was improved by focusing on inter-item relatedness to allow for inter-item cueing.

Neither encoding strategy was beneficial for the alternative retention test. However, Roediger and McDermott (1995) add that thematic clustering of stimuli can also be detrimental to performance and lead to false memories being created, such as erroneously recalling the word ‘sleep’ after having viewed the words ‘bed’, ‘rest’ and ‘awake’. As a result of her findings, Tversky (1973) theorised that in order to achieve optimum performance on a recall or recognition test, participants need to encode qualitatively different information, rather than merely different amounts of information as had been previously suggested (Postman, 1963).

The Role of Encoding in Picture and Word Processing

As discussed in previous chapters, a main concern of the current body of work lies in the differences when processing verbal and non-verbal material (i.e. pictures and words) and how these can be combined into a single meaningful stimulus, allowing both types of processing to coincide. Superior retention for pictures has been shown to occur in both recall and recognition tests (Standing, 1973). To explain the occurrence of the picture superiority effect (Gadzella & Whitehead, 1975; Wicker, 1971; Hasher, Riebman & Wren, 1976) it has been suggested repeatedly that the key difference can be found in how these stimuli are encoded during initial processing (Paivio, 1971; Durso & Johnson, 1980). Nelson, Reed and McEvoy (1977b) present a model reminiscent of Paivio’s (1971) dual coding theory. With studies repeatedly showing improved recall for pictures over words (e.g. Paivio, Rogers & Smythe, 1968; Shepard, 1967) they put forward a sensory semantic model of processing. The model suggests that pictures have more distinctive sensory codes than words and are more likely to be processed semantically upon first viewing. As a result, pictures directly activate meaning, while words will activate phonemic codes before meaning and in some cases meaning may not be activated at all (Craik & Lockhart, 1972; Brown & McNeill, 1966). On the other hand, when words are encoded semantically, retention rises significantly and they are almost on par with pictures (D'Agostino, O'Neill & Paivio, 1977). Later studies, using elaborate semantic encoding for words, even successfully reversed the picture superiority effect with higher retention observed for words than picture stimuli (Durso & Johnson, 1980). Durso and Johson (1980) also discovered that superior recall for pictures could be eliminated when participants were instructed to process line drawings purely as abstract symbols rather than meaningful pictures – similar to the structural level of processing for words (Craik & Lockhart, 1972). In turn, Bower, Karlin and Dueck (1975) presented participants with a series of nonsense drawings. One group saw the images without explanation, while a second group was given explanations of what each image showed. Participants who received an explanation were more able to contextualise the images, leading to increased accuracy for both recall and recognition tests. These findings clearly demonstrate the importance of stimulus encoding, conceptual processing and the impact it has on likelihood of retention. Hereby, the nature of the encoded information and the pattern of node activation within the semantic network play a more prominent role than merely the amount of information encoded in relation to a stimulus (D'Agostino, O'Neill & Paivio, 1977; Durso & Johnson, 1980).

When verbal and non-verbal information is combined meaningfully it will often compliment one another and aid both encoding and retention (Garner, 1976; Gajewski & Brockmole, 2006; Glenberg & Langston, 1992). Congruent verbal and non-verbal stimuli can encourage in-depth processing (Gajewski & Brockmole, 2006), increase processing speed (Stroop, 1935), and enhance learning of new material (Glenberg & Langston, 1992). However, it should be noted that in some instances, detailed and plausible verbal information can overshadow existing memory (Schooler & Engstler-Schooler, 1990) or even create entirely new memories of events that never occurred (Pezdek & Hodge, 1999). This is particularly likely to occur for childhood memories of a period when mental structures are not yet fully formed and recollection is more open to suggestion and recounting of events that are not accurately recalled by an individual themselves (Hyman & Billings, 1999; Hyman, Husband & Billings, 1995). As such, extensive rehearsal may lead to alteration of the memory trace, reducing recall accuracy (Schooler & Engstler-Schooler, 1990).

The Present Experiments

Findings presented in Chapter 4 showed that while the unfamiliar stimulus format still led to slower response times in self-paced trials, recall scores were not affected by presentation format in incidental recall. When exposure time was fixed at a short interval (2000ms) recall scores were equally unaffected in a surprise recall test. When participants were made aware of the recall test, performance improved for integrated congruent and control stimuli, with native speakers showing no difference between the two. With extended exposure time, recall improved for all stimuli but the overall pattern mirrored that of the shorter exposure duration.

Eagle and Leiter (1964) suggest that incidental recall may not be appropriately tested by using a free recall paradigm and that a more accurate measure of incidental encoding may be achieved by testing participants' recognition of previously presented stimuli. To this end, the current chapter aims to investigate both the effect of intentional versus incidental encoding as well as the impact of the retention test used. In order to directly compare incidental and intentional memory, directed forgetting was used. While half of the items presented will be intentionally encoded by participants, the remaining half will be deemed irrelevant, therefore making any instances of positive recall or recognition a result of incidental encoding. This methodology both allows a direct comparison between intentional and incidental encoding as well as an examination of the memorability and recognisability of integrated stimuli under conditions where typical patterns for verbal and non-verbal materials are well documented (Cahill et al., 1994; Doerksen & Shimamura, 2001; Nagae & Moscovitch, 2002 and Bradley et al., 1992 for words and pictures, respectively).

Experiment 9 tested directed forgetting of integrated and control stimuli using a free recall test. If integration of verbal and non-verbal material into a single stimulus leads to more extensive processing, facilitating faster access to semantic node activation, it would be expected that forgetting will be less pronounced in integrated compared to control stimuli (Basden & Basden, 1996; Hauswald & Kissler, 2008). In order to detect more subtle effects of incidental encoding, Experiment 10 used a recognition test. It is possible that the full extent to which integrated stimuli are retained in memory might not be observed in a free recall test and therefore using both tests independently will allow for any differences depending on encoding or retrieval processes to be detected (Eagle & Leiter, 1964). The final experiment directly examined whether verbal or non-verbal material was more readily utilised by participants by presenting the to be recognised items as either words or pictures, following participants' viewing of integrated target items. It is expected that overall accuracy will be higher for recognition than recall (MacDougall, 1904) and that integrated stimuli will be less susceptible to the impact of directed forgetting than control words.

Experiment 9

Experiment 9 was designed to investigate integrated and control stimuli in a direct comparison of incidental and intentional encoding conditions. A directed forgetting approach was chosen as this allows incidental and intentional processing to occur side by side, while comparing integrated and control items directly in under both encoding conditions. Participants are focused on committing half the stimuli to memory, whereas the other half is to be ignored and deemed irrelevant for later stages of the study, although retrieval of all stimuli will be required at recall. While participants expect to be tested on the to be remembered stimuli, testing for the to be forgotten items is unexpected. Less prominent differences may become more obvious in this design, since between participant variance becomes irrelevant. This will eliminate the confounding effect of any baseline differences in memory performance of individual participants.

The experiment aims to test how integrated items are encoded and whether they are processed primarily on a verbal or non-verbal level. Previous research has identified significant differences in how verbal (Bjork, 1970; Paller, 1990) and non-verbal (Basden & Basden, 1996; Lehman et al., 1998) material is encoded under directed forgetting instructions. Findings have shown that picture stimuli are significantly less susceptible to directed forgetting effects than words. This lack of an effect for words, has mainly been attributed to the type of processing pictures undergo compared to words, with pictures allowing faster access to semantic information and more widespread conceptual activation (Stenberg, 2006; Stenberg, Radeborg & Hedman, 1995). Golding et al. (1994) have shown that semantic processing leads to higher retention rates. While semantic processing occurs automatically for pictures (Nelson et al., 1977b) unless encoding instructions to the contrary are explicitly given

(Durso & Johnson, 1980), it can also occur for verbal material. The likelihood increases depending on the suitability of the to be studied materials for semantic processing (Geiselman, 1974) as well as the specific encoding instructions given (Craik & Lockhart, 1972). If integration of verbal and non-verbal material leads to increased semantic processing and more widespread node activation for a given concept, this should be reflected in the magnitude of the directed forgetting effect observed for integrated compared to control stimuli; that is, integrated items should be less likely to be forgotten than control words.

Encoding cues were presented as either 'remember' or 'forget' and were presented alongside each target (Paller, 1990). Presentation format was manipulated using both integrated and control stimuli. Free recall was used as a retention test. On the basis of previous findings (McNally et al., 2004; Paller, 1990), it is also expected that R items will produce better recall in comparison to F items.

As in previous chapters, native language will be recorded and analysed due to the strong linguistic nature of the stimuli, designed to draw upon the association between pictorial object representation and verbal labels, which is likely to be more strongly established in native than non-native speakers (da Costa Pinto, 1991).

Methodology

Participants. Forty undergraduate students participated in the experiment on a voluntary basis. The majority of respondents were female (25; 62.5%). Ages ranged from 18 to 50 with a mean age of 26.33 years (SD=9.10 years). Almost three quarters (29; 72.5%) identified themselves as native speakers, while the remaining students spoke English as a second language. The majority of the sample was Black (37.5%), followed by White (32.5%), Asian (20%) and mixed ethnic heritage (5%). Two participants reported other ethnic origins (5%).

Design. The experiment was run in a mixed design, where participants responded to stimuli of all types. Two repeated measures variables were used: Presentation format where items were presented either in integrated (where features matched the meaning of the word) or control (which consisted of words written in standard lower case letters) format and encoding instructions, where participants were instructed to either remember or forget the individual item, resulting in four experiment conditions: To be remembered integrated items – integrated R, to be forgotten integrated items – integrated F, to be remembered control items – control R and to be forgotten control items – control F. Stimuli were presented in a randomised, mixed list and counterbalanced for both presentation format and encoding instructions. In addition, native language was measured as a between subjects factor. Number of correctly recalled words was recorded.

Apparatus. The experiment was presented on Superlab version 4.0.7b running on Macbook Air with an Intel Core i5 processor (1.7GHz) using OS X Yosemite. Stimuli were displayed on a 11" flat screen monitor at a resolution of 1366x768px.

Stimuli. Thirty-two words were used with eight assigned to each condition. Stimuli in the integrated condition were manipulated in terms of colour, global shape, individual letter orientation, font and spatial distribution of letters to achieve a picture like character for each stimulus allowing it to physically resemble the object it described. Examples of stimuli are shown in Figure 4.1 below.

Figure 5.1: Examples of stimuli used. From left to right: integrated R, integrated F, control R, control F.

Procedure. Participants provided demographic data and consent in writing before starting the experiment. They then completed the experiment individually on a computer. All instructions were provided onscreen and they were given the opportunity to ask questions. Participants were presented with 32 trials and for each were instructed to either remember of forget the individual item. Each item was shown for 3000ms. After viewing all items, participants were then presented with a surprise recall test and asked to write down as many of the items as they could remember regardless of encoding instructions. Participants were then debriefed and given another opportunity to ask any questions.

Results

Descriptive statistics displaying means and standard deviations for recognition scores can be seen in Table 5.1 below.

Table 5.1: Means and standard deviations of recall scores for native and non-native speakers across presentation formats.

	recall scores

		mean	SD
integrated remember	native speakers	3.41	1.94
	non-native speakers	2.09	1.04
integrated forget	native speakers	0.59	1.09
	non-native speakers	0.55	0.69
control remember	native speakers	3	1.83
	non-native speakers	2.18	1.72
control forget	native speakers	0.62	0.98
	non-native speakers	0.18	0.4

A mixed measures 2x2x2 ANOVA was used to analyse the data, with encoding cue and presentation format as within subject factors and native language as a between subjects factor. A significant main effect was found for encoding cue, F(1, 38)=58.699, p<0.001, η_p^2 =0.607, and native speaker, F (1, 38)= 5.193, p=0.028, η_p^2 =0.12. No main effect was observed for presentation format, F(1, 38)<1, p=0.46, η_p^2 =0.053. No interactions were observed between encoding cue and presentation format, F(1, 38)<1, p=0.994, η_p^2 <0.001, encoding cue and native language, F(1, 38)=2.115, p=0.154, η_p^2 =0.053, or presentation format and native language, F(1, 38)<1, p=0.903, η_p^2 <0.001. No significant three way interaction was found, F(1, 38)=1.261, p=0.269, η_p^2 =0.032.

Bonferroni post-hoc analysis revealed that integrated R stimuli were recalled significantly better than both integrated F and control F stimuli (p<0.001 for both), but did not differ from control R stimuli (p=1). In addition control R stimuli were recalled significantly better than control F stimuli (p<0.001). No other differences were found.

Results also showed that native speakers recalled more integrated items than non-native speakers under remember instructions, t(38)=2.139, p=0.039, while no significant difference was observed for control stimuli, t(38)=1.281, p=0.208.

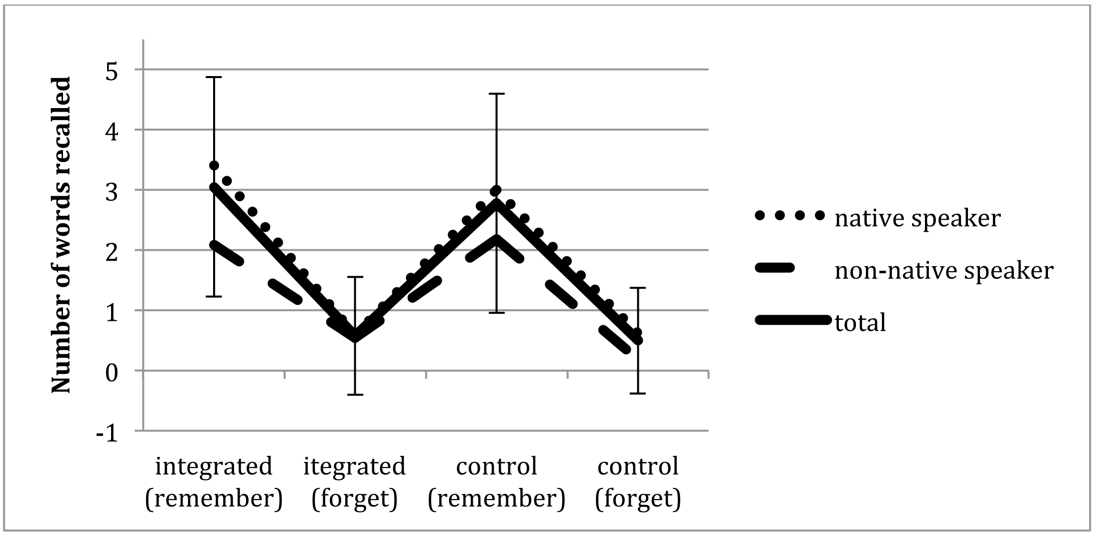

Figure 5.2: Means and standard deviations of recall scores for native and non-native speakers for both types of stimuli under remember and forget instructions.

Discussion

Experiment 9 compared integrated and control stimuli under incidental and intentional encoding conditions in a directed forgetting paradigm, using a free recall test. Since picture stimuli and other material suitable for semantic processing have been found to be less susceptible to directed forgetting (Golding et al., 1994; Sahakyan & Delaney, 2003; Geiselman, 1974), the findings from this experiment allow an insight into whether integrated stimuli are processed primarily as words or whether the enhanced features facilitate faster semantic access.

Results demonstrated a clear effect of directed forgetting, with R words significantly outperforming F words for both types of stimuli (Basden & Basden, 1996; Golding et al., 1994). At first glance, this suggests that both integrated and control words were equally susceptible to directed forgetting instructions. These results may mean that both presentation formats are processed primarily on a verbal level, employing highly similar encoding mechanisms. Picture stimuli have demonstrated higher resistance to directed forgetting than words (Basden & Basden, 1996; Lehman et al., 2001; Lehman et al., 1998; Hauswald & Kissler, 2008) but findings suggest that pictorial features were unsuccessful in altering processing strategy under current experimental conditions. This was also evident in the absence of an effect of presentation format. Not only were integrated stimuli and control stimuli equally affected by directions to forget, but integrated stimuli did not derive an independent advantage as a result of verbal and non-verbal integration.

Native speakers recalled more words overall than did non-native speakers. No difference was observed between integrated and control items, with the exception of native language resulting in significantly better recall of integrated items under R instructions. Results from previous experiments had already indicated on a number of occasions that native speakers are more capable of using features of integrated items to aid recognition and recall of these stimuli. The current findings are compatible with the assumption that this advantage may arise from a push towards processing items on a semantic rather than a phonemic or orthographic level (Craik & Lockhart, 1972). It also suggests that native speakers were more successful in using both verbal and non-verbal information to form a more wholistic memory trace since no difference occurred in control items, which were processed in a similar manner by both native and non-native speakers. This benefit is likely attributable to the stronger conceptual link between pictures, words and real life objects for native speakers, for whom this association has been reinforced throughout their lifetime (da Costa Pinto, 1991).

Recall rates for F items from both types of stimuli were equally low and showed no differences as a result of native language. If integrated items were indeed processed semantically, it would have been expected that more items would be recalled for integrated stimuli than control stimuli regardless of instructions to forget (Golding et al., 1994). This was not the case in the current experimental design. However, as it has been pointed out (Eagle & Leiter, 1964), a free recall test may not effectively measure retention of incidentally encoded material. It is consequently possible that F items were encoded, but could not be recalled, perhaps as a result of unconscious inhibition or low sensitivity of the retention test. Therefore, Experiment 10 employed a recognition test to examine item retention.

Experiment 10

While Experiment 9 made use of a free recall paradigm, Experiment 10 was designed to index any potential effects of integrated stimuli in incidental encoding that may not have been detected by a less sensitive retention test, such as free recall. While the experiment was similar to the previous in most respects, the retention test was changed from free recall to recognition. Variables were manipulated in the same way as in Experiment 9. Since integrated items are of a highly novel and unfamiliar nature, its is likely that recognition and encoding will result in greater effort and more elaborate processing, which could have a beneficial impact on memory. Alternatively, it could also be argued that as a result of their unusual and complex appearance, constructing a coherent memory trace from which the item can be reliably retrieved may be rendered more difficult. While these items could be easily recognisable, more systematic exposure and familiarisation may be needed for effective storage and retrieval processes to take effect and for integrated stimuli to be fully represented and incorporated within already established schemata.

In addition to correct recognition scores, reaction times were also measured for recognition response latencies. While this is not common practice in directed forgetting (MacLeod, 1989), previous research has occasionally examined reaction times (Epstein et al., 1975; Howard, 1976; Fawcett & Taylor, 2008) and since one of the main unanswered questions regarding integrated stimuli concerns the processes by which they are encoded, reaction times are likely to provide valuable data to draw upon when trying to understand how these stimuli are processed. A typical pattern of response times has not yet been established, with varied results having been obtained, suggesting either longer response latencies for R words (Epstein et al., 1975; Howard, 1976) or F words (Fawcett & Taylor, 2008). It should however be noted that while the studies which found longer response times for R items (Epstein et al., 1975; Howard, 1976) used associate pairs as stimuli, the study reporting longer response latencies for F items used single nouns as targets (Fawcett & Taylor, 2008). It is plausible to imagine that associate pairs would require more elaborate processing for R trials to firstly establish a mental link between the two items and secondly commit the pair to memory. None of these additional processes would be required for F trials, which as a result are likely to leave a considerably weaker memory trace. Consequently, at recognition, more information would be retained in memory in regard to R items, which may result in additional processing time being required to verify whether or not an item had been viewed previously while also increasing accuracy. In contrast, very little information would be retained about F items, leading to faster rejection of targets. For single nouns, on the other hand, similar amounts of information could be encoded for both R and F items. While it has repeatedly been shown that this is effective in differentiating R items at recognition with relative certainty (Reitman et al., 1973; Epstein et al., 1972), it may also lead to less confident decisions regarding F items as participants may experience greater uncertainty in deciding whether or not items had been previously viewed, which would result in increased response latency for F items. Correlational analysis exploring the relationship between response times and recognition accuracy could help clarify which process is more likely to underlie response latency patterns. If longer responses are a result of a larger amount of encoded information which needs to be processed, longer processing time should result in higher accuracy. If, on the other hand, extended response latencies are a result of uncertainty about whether or not items had been previously seen, increased response times would likely be associated with a reduction in recognition accuracy.

Due to the more complex nature of integrated stimuli, it would be reasonable to assume that these stimuli would also be subject to more elaborate processing. With participants required to draw a link between the verbal and non-verbal dimension of the stimulus, it is likely that a similar pattern as for word pairs would be observed, producing longer responses on R words for integrated stimuli. In contrast, control items are more likely to behave similar to single nouns, meaning that response latency for control items should be shorter on R than F items.

As in Experiment 9, it is expected that if integrated stimuli do benefit from more semantic processing, they will be less susceptible to directed forgetting. Any previously undetected differences in incidental encoding should become apparent by changing the retention test method from recall to recognition (Eagle & Leiter, 1964). Based on the results obtained in Experiment 9, findings presented in earlier chapters and previous research (da Costa Pinto, 1991), it is also expected that native speakers will be able to utilise integrated stimuli more easily than non-native speakers.

Methodology

Participants. Forty undergraduate students participated in the experiment on a voluntary basis. The majority of the sample was female (25; 62.5%). Ages ranged from 18 to 51 with a mean age of 27.3 years (SD=10.36 years). Sixty-five percent of the sample (26) identified themselves as native speakers, while the remaining students spoke English as a second language. Just over one third of the sample was White (35%), followed by Asian (32.5%), and Black (27.5%). One participant identified as being of mixed ethnic heritage (2.5%) and another stated other ethnic origins.

Design. Variables and conditions were identical to Experiment 9, but instead of administering a free recall test, recognition accuracy was measured. Both recognition times and number of correctly recognised words were recorded in this study.

Stimuli & Apparatus. The same stimuli and apparatus as in Experiment 9 were used.

Procedure. The procedure was identical to Experiment 9 for the initial presentation of stimuli. After viewing all items, participants were then presented with a recognition phase, where the same items were shown once more in random order. Participants were asked to indicate for each item whether or not they had seen it during the initial presentation phase. In light on the directed forgetting manipulation of encoding, no distractors were used. Participants were then debriefed and given another opportunity to ask any questions.

Results

Descriptive statistics displaying means and standard deviations for both dependent variables can be seen in Table 5.1 below.

Table 5.2: Means and standard deviations for recognition times and recognition accuracy for native and non-native speakers across presentation formats.

		recognition times		recognition scores	
		mean	SD	mean	SD
integrated remember	native speakers	2378.98	1713.74	7.15	1.12
	non-native speakers	1836.83	857.74	6.38	1.39
integrated forget	native speakers	1737.08	529.8	5.23	2.6
	non-native speakers	1747.89	541.94	4.85	2.85
control remember	native speakers	1372.76	245.79	5.96	1.54
	non-native speakers	1395.42	433.46	5.23	1.79
control forget	native speakers	1694.51	277.89	4.54	2.16
	non-native speakers	1598.6	703.55	4.62	1.61

Reaction times. A mixed measures 2x2x2 ANOVA was used to analyse the data, with encoding cue and presentation format as within subject factors and native language as a between subjects factor. No significant main effects were found for presentation format, $F(1, 38)=2.029$, $p=0.163$, $\eta_p^2=0.051$, encoding cue, $F(1, 38)<1$, $p=0.327$, $\eta_p^2=0.025$, or native language, $F(1, 38)<1$, $p=0.603$, $\eta_p^2=0.007$. No significant interactions were found between encoding cue and presentation format, $F(1, 38)<1$, $p=0.544$, $\eta_p^2=0.01$, encoding cue and native language, $F(1, 38)<1$, $p=0.733$, $\eta_p^2=0.003$, or presentation format and native language, $F(1, 15)<1$, $p=0.914$, $\eta_p^2<0.001$. No three way interaction was found, $F(1, 38)<1$, $p=0.129$, $\eta_p^2=0.003$.

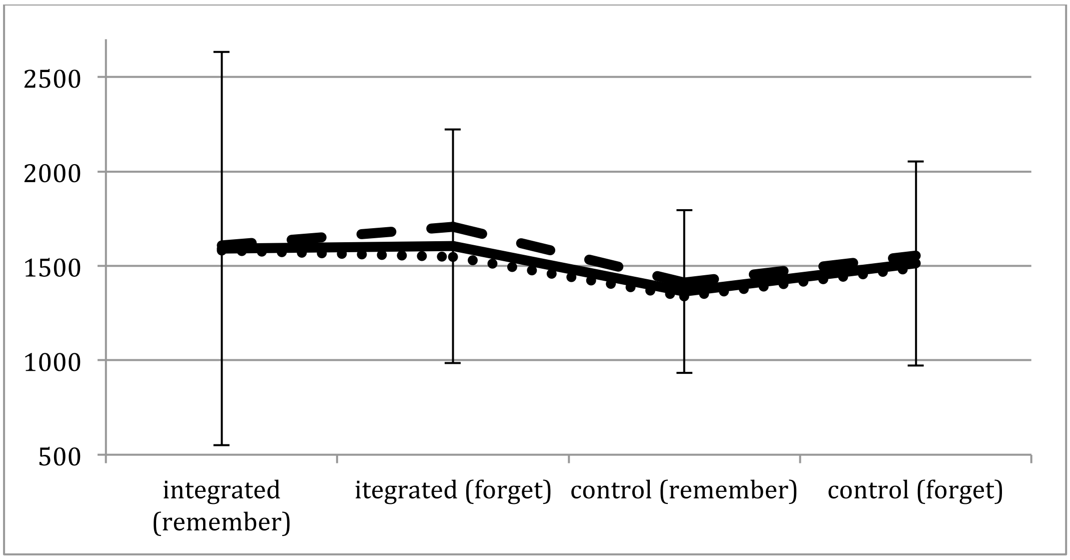

Figure 5.3: Means and standard deviations of response times for native and non-native speakers for integrated and control stimuli under remember and forget instructions.

Recognition scores. A second 2x2x2 mixed measures ANOVA was run to examine recognition scores. Significant main effects were detected for encoding cue, F(1, 37)=12.285, p=0.001, η_p^2 =0.249, and presentation format, F(1, 37)=10.088, p=0.003, η_p^2 =0.214. No significant main effect was found for native language, F(1, 37)=1.081, p=0.305, η_p^2 =0.028. A marginal interaction was found between encoding cue and presentation format, F(1, 37)=3.974, p=0.054, η_p^2 =0.097. No significant interactions were found between encoding cue and native language, F(1, 37)<1, p=0.452, η_p^2 =0.015, or between presentation format and native language, F(1, 37)<1, p=0.63, η_p^2 =0.006. No three way interaction was found, F(1, 37)<1, p=0.557, η_p^2 =0.009.

Analysis of simple effects through Bonferroni analysis showed that R items were more likely to be recognised than F items, p=0.001, and that integrated items were more likely to be recognised than control items, p=0.003. Further post-hoc analysis revealed that integrated R stimuli produced significantly higher recognition scores than integrated F stimuli (p=0.003), control R stimuli (p=0.001) and control F stimuli (p<0.001). In addition control R stimuli were recognised marginally better than control F stimuli (p=0.097). A post-hoc Tukey test revealed that while native speakers recognised more integrated R items than non-native speakers, the difference fell short of significance (p=0.07); native and non-native speakers did not differ significantly in their recognition of control stimuli (p=0.193). No other differences were found.

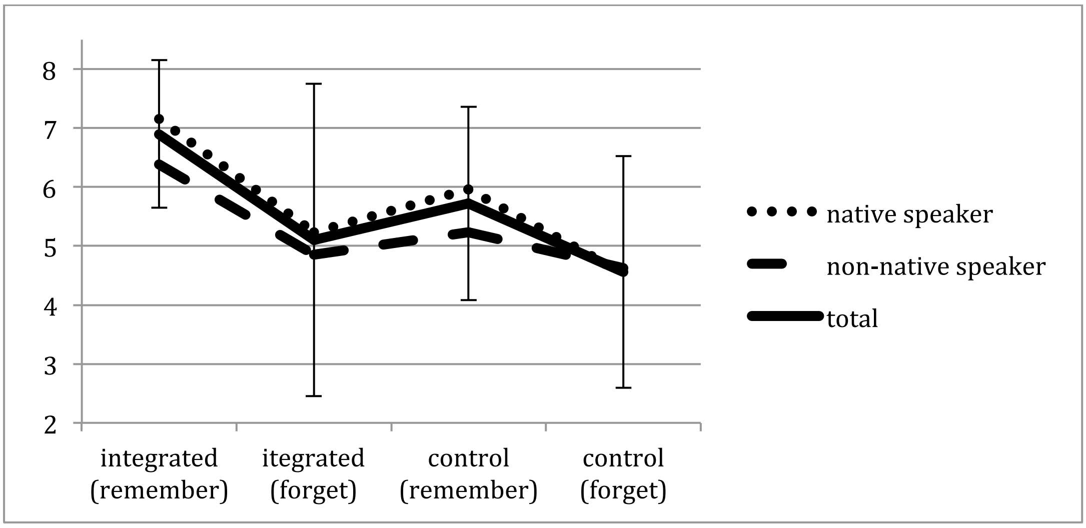

Figure 5.4: Means and standard deviations of recognition scores for native and non-native speakers for both types of stimuli under remember and forget instructions.

Correlations between recognition accuracy and response latencies. Since the relationship between recognition accuracy and response latency has received little attention and the relationship is still unclear as a result of varying results and methodology, Pearson correlations were run to investigate any potential links between the two. This will allow conclusions to be drawn regarding the processes involved in encoding of integrated compared to control stimuli under incidental and intentional encoding conditions. Response latencies often show greater sensitivity to small effects than error rates and since no significant effect for response times were revealed through the ANOVA, additional, retrospective analysis was carried out. Significant negative correlations were present for integrated stimuli under both encoding instructions. No correlation was found between reaction times and recall scores for control R stimuli, while a marginal negative correlation emerged for control F items.

Table 5.3: Correlations between recognition accuracy and response latency across conditions

Condition	r	p
integrated (remember)	-.412	.008
integrated (forget)	-.326	.046
control (remember)	-.146	.374
control (forget)	-.301	.067

Discussion

Experiment 10 largely replicated the design of Experiment 9, but used recognition instead of free recall as a retention test. Recognition has been found to be more sensitive to memory traces resulting from incidental encoding (Eagle & Leiter, 1964) than free recall. Thus, the current experiment was designed to detect encoding differences between integrated and control stimuli in the to be forgotten items that may not have been detected in the previous experimental design.

While no significant effects were found for response times, with the use of a recognition test, reaction times tentatively followed a trend predicted if integrated stimuli resulted in more elaborate processing than control stimuli. Integrated stimuli produced slightly longer response times for R items (Epstein et al., 1975; Howard, 1976), whereas control stimuli yielded just minutely longer response latencies for F stimuli (Fawcett & Taylor, 2008), although clearly no reliable conclusions can be drawn from these data.

A more refined pattern emerged for recognition accuracy. In line with previous findings, recognition scores were higher than recall scores across all conditions (MacDougall, 1904). While overall more R than F trials were recognised correctly, this difference only remained significant for integrated stimuli, but not control items when tested separately. The data showed a clear recognition advantage for integrated over control items, with significantly higher recognition scores recorded. In fact, while integrated R items outperformed all other types of stimuli on recognition accuracy, control R stimuli did not differ significantly from integrated F stimuli. The results therefore show that incidentally encoded integrated items are recognised as accurately as intentionally encoded control words. Thus, when using a retention test sensitive to incidentally encoded material, integrated stimuli display a recognition pattern more resistant to the effect of directed forgetting than that observed for control items, as well as being significantly more recognisable overall. This supports the assumption that integrated stimuli are more readily processed on a semantic level than control items. As in previous experiments, native speakers were once more observed to derive greater benefit from integrated items than non-native speakers (da Costa Pinto, 1991).

Results obtained from correlational analysis between recognition accuracy and response times are in favour of an uncertainty hypothesis. Negative correlations were found for integrated stimuli under both remember and forget instructions and a marginal negative correlation was observed for control stimuli when directions to forget were given. Clearly, as response latencies increase, accuracy reduces. This seems to suggest that participants were unable to come to a fast and definite conclusion whether or not they recognised items from the presentation phase. Some uncertainty may be a product on incomplete mental representation of stimuli being formed (O'Regan & Clark, 1997). Resulting from the complex nature of integrated items, participants may feel unable to assess whether small-scale changes have occurred in the more detailed aspects of the stimulus. A smaller trend was observed for control stimuli under directed forgetting conditions, where uncertainty would likely have occurred because of incomplete encoding or lack of attention paid to these items.

Experiment 11

Experiment 10 established a distinct pattern for integrated stimuli compared to control stimuli under directed forgetting instructions when recognition is used as a retention test. These results are suggestive of semantic processing being used to encode these items. Experiment 11 was designed to assess whether verbal or non-verbal information is of primary importance when processing integrated items and which dimension leads to faster, more accurate recognition. Directed forgetting was once again used during presentation and participants were instructed to either remember or forget each stimulus. All items were now presented in integrated format. Unlike in the previous experiments, recognition format was altered and objects were now shown as either standard words or standard pictures during the recognition phase. This methodology allowed for addressing two questions. Firstly whether participants based recognition judgements primarily on verbal or non-verbal information of integrated stimuli and secondly whether verbal and non-verbal material was processed differently in incidental and intentional encoding. This will clarify whether the verbal or non-verbal dimension is used as a primary referent during recognition. If participants base recognition judgements primarily on verbal features, recognition judgements of words should be faster and more accurate. If, on the other hand, non-verbal information is primarily used in recognition judgements, pictures should be recognised faster and more accurately. If both dimensions exert equal impact on recognition, no difference should be observed between word and picture recognition. The experiment therefore is of a more exploratory nature, investigating the processes involved in encoding, comprehending and recognising integrated material.

Based on findings from Experiment 10 as well as earlier results obtained by Fawcett and Taylor (2008), it is expected that reaction times will be slower for F than R items, since uncertainty is likely to be higher in F stimuli. Pictures are also expected to produce longer response times since a greater amount of encoded information (Nelson et al., 1977b; Paivio, 1971) as well as a higher level of dissimilarity between encoded and to be recognised material is likely to result in increased uncertainty and longer response latencies when making a recognition judgement.

Methodology

Participants. Forty undergraduate students participated in the experiment on a voluntary basis. The majority of respondents were female (27; 67.5%). Ages ranged from 18 to 48 with a mean age of 24.9 years (SD=6.52 years). Just under half of the sample (18; 45%) identified themselves as native speakers, while the remaining students spoke English as a second language. The majority of the sample was Asian (30%) or Black (30%), followed by White (22.5%), participants of mixed ethnic heritage (10%) and Chinese (5%). One participant reported other ethnic origins (2.5%).

Design. The experiment was run as a mixed measures design, where participants responded to stimuli of all types. Two within subject variables were used: Type of encoding instructions – remember/forget items – and recognition format –

verbal/non-verbal. During the presentation phase all stimuli were shown in integrated format and participants were instructed to either remember or forget each item. Presentation order was randomised. During the recognition phase the items were shown once again but this time they were displayed as either pictures (non-verbal) or words (verbal). This resulted in four experimental conditions: R pictures, F pictures, R words and F words. Stimuli were presented in a mixed, randomised list and counterbalanced for both encoding instructions and recognition format. Native language was measured between subjects. Reaction times and number of correctly recognised items were recorded.

Apparatus. The same apparatus was used as in Experiment 10.

Stimuli. The same 32 words as in Experiment 9 and 10 were used with eight assigned to each condition. During the presentation phase, all items were shown in integrated format. For the recognition phase both pictures and words referring to the same 32 items were used. Examples of stimuli are shown in Figure 4.5 below.

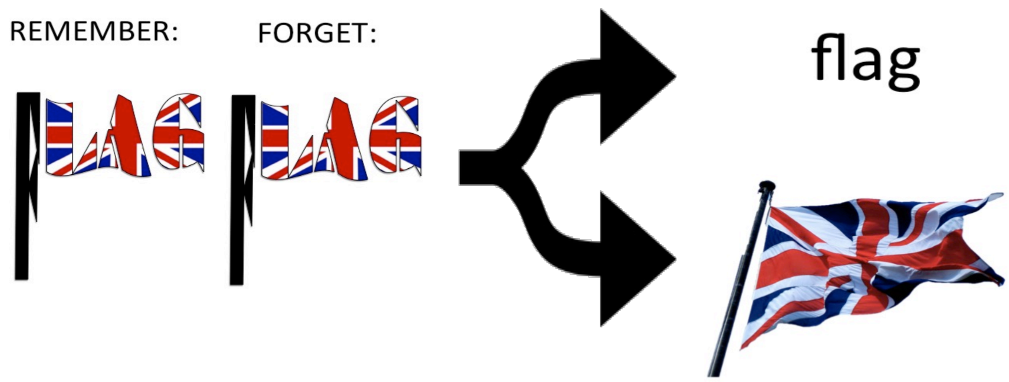

Figure 5.5: Stimuli used in the presentation (left) and recognition phase (right)

Procedure. Participants provided demographic data and consent in writing before starting the experiment. They then completed the experiment individually on a computer. All instructions were provided onscreen and they were given the opportunity to ask questions. Participants were presented with 32 trials and for each were instructed to either remember of forget the individual item. Each item was shown for 3000ms. Following completion of the presentation phase, participants entered the recognition phase. They were presented with a series of words and pictures and for each trial were asked to indicate whether the object had been included in the initial presentation phase.

Results

Descriptive statistics displaying means and standard deviations for both dependent variables can be seen in Table 5.4 below.

Table 5.4: Means and standard deviations for recognition times and recognition accuracy for native and non-native speakers across presentation formats.

		recognition times		**recognition scores**	
		mean	**SD**	**mean**	**SD**
remember pictures	native speakers	1710.97	813.4	4.76	1.75
	non-native speakers	1640.7	435.02	4.27	2.23
forget pictures	native speakers	1841.39	887.23	3.29	1.69
	non-native speakers	1650.86	439.94	2.5	1.95
remember words	native speakers	1543.37	679.98	5.82	1.29
	non-native speakers	1487.26	366.79	4.91	1.48
forget words	native speakers	1538.31	656.26	3.88	1.58
	non-native speakers	1615.91	511.13	3.55	2.02

Reaction times. A mixed measures 2x2x2 ANOVA was used to analyse the data, with encoding cue and recognition format as within subject factors and native language as a between subjects factor. A significant main effect was found for recognition format, $F(1, 38)=7.663$, $p=0.009$, $\eta_p^2=0.168$. No significant main effects were detected for encoding cue, $F(1, 38)=1.55$, $p=0.221$, $\eta_p^2=0.039$, or native language, $F(1, 38)<1$, $p=0.727$, $\eta_p^2=0.003$. No significant interactions were found between encoding cue and recognition format, $F(1, 38)<1$, $p=0.925$, $\eta_p^2<0.001$, encoding cue and native language, $F(1, 38)<1$, $p=0.95$, $\eta_p^2<0.001$, or recognition format and native language, $F(1, 38)=1.406$, $p=0.243$, $\eta_p^2=0.036$. The three way interaction was not significant, $F(1, 38)=2.012$, $p=0.164$, $\eta_p^2=0.05$.

Analysis of simple effects through Bonferroni post-hoc analysis revealed that words were responded to faster than pictures, p=0.009. Further post-hoc analysis revealed that verbal R items were responded to faster than non-verbal F items, p=0.003. The difference between verbal R items and non-verbal R items approached significance, p=0.069.

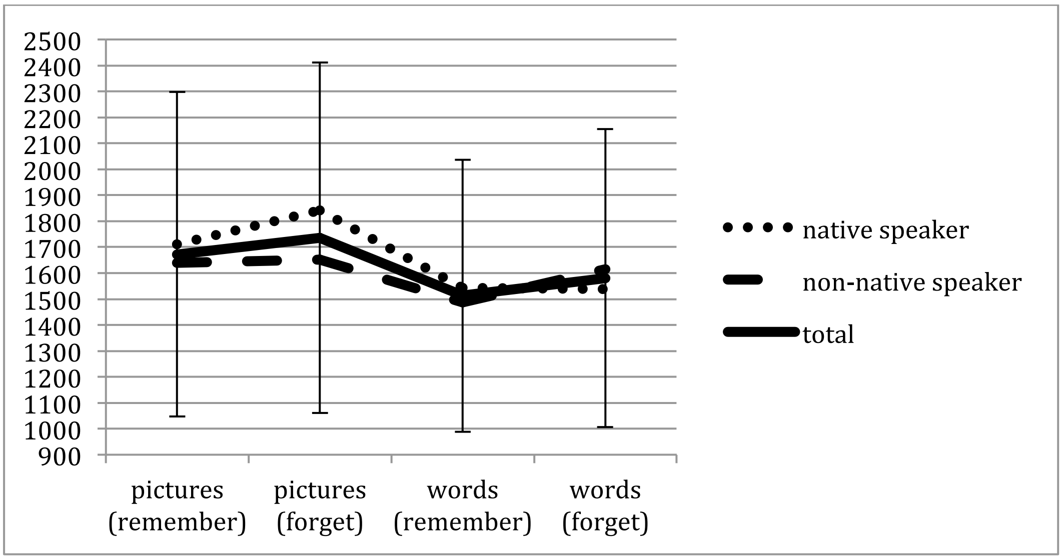

Figure 5.6: Means and standard deviations of response latencies for recognition of targets as either pictures or words after being encoded under remember or forget instructions.

Recognition scores. A second 2x2x2 mixed measures ANOVA was run to examine recognition scores. Significant main effects were detected for encoding cue, $F(1, 37)=29.444$, $p<0.001$, $\eta_p^2=0.443$, and recognition format, $F(1, 37)=17.982$, $p<0.001$, $\eta_p^2=0.327$. No significant main effect was found for native language, $F(1, 37)=2.438$, $p=0.127$, $\eta_p^2=0.062$. No significant interactions were found between encoding cue and recognition format, $F(1, 37)=1.186$, $p=0.283$, $\eta_p^2=0.031$, encoding cue and native language, $F(1, 37)<1$, $p=0.821$, $\eta_p^2=0.001$, or recognition format and native language, $F(1, 37)<1$, $p=0.965$, $\eta_p^2<0.001$. The three way interaction was not significant, $F(1, 37)=1.186$, $p=0.283$, $\eta_p^2=0.031$.

Analysis of simple effects using Bonferroni post-hoc analysis showed that R items were more likely to be recognised than F stimuli, $p<0.001$, and words were more likely to be recognised than pictures, $p<0.001$. Post-hoc analysis further revealed that highest recognition accuracy was observed for R words, which were recognised more accurately than R pictures ($p=0.038$), F words ($p<0.001$) and F pictures ($p<0.001$). Furthermore, R pictures were recognised more accurately than F pictures ($p=0.002$) and F words were recognised more accurately than F pictures ($p=0.027$). No difference was observed between R pictures and F words ($p=0.260$).

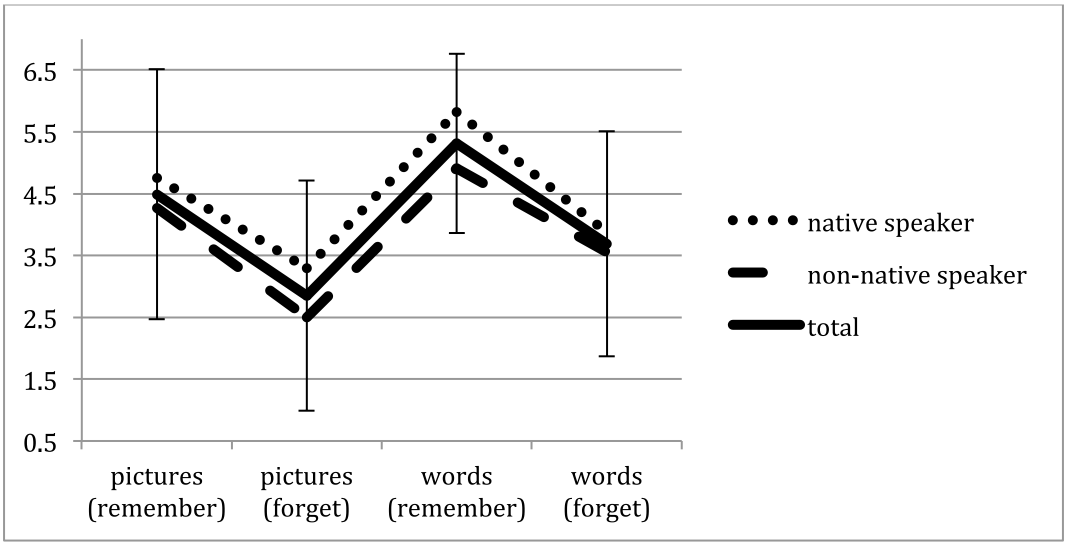

Figure 5.7: Means and standard deviations for recognition accuracy of targets encoded under remember or forget instructions when recognised as either pictures or words.

Discussion

Experiment 11 was designed to examine whether integrated stimuli were recognised using primarily verbal or non-verbal information. All stimuli were initially presented in integrated format with either remember or forget instructions, while recognition trials were presented as either standard words or standard pictures.

As predicted on the basis on an uncertainty hypothesis, response latencies exhibited a slight trend toward shorter response times for R than F trials for both recognition formats, although the effect failed to reach significance. A significant effect was observed for recognition format, with pictures producing longer response times than words. While this could be an indication of less effective encoding and recognition of non-verbal information, this pattern would also be predicted under an uncertainty hypothesis of recognition judgements since pictures contain more detailed information, which can lead to greater uncertainty when judging whether an items has been previously seen. In addition, for successful recognition to occur in this design, verbal and non-verbal information needs to be separated to an extent to allow recognition of dimensions independently. When looking at pictures, non-verbal information is often extracted, abstracted and organised into existing knowledge. In contrast, simple verbal information – such as a single word – requires little processing and can be stored directly in its existing format. The additional processing effort required might in part explain the longer response times for non-verbal items.

As expected, R items were recognised more accurately than F items. In addition, participants were more likely to recognise stimuli presented as words than pictures. This suggests that integrated stimuli were processed primarily on a verbal level, with verbal information more likely to lead to recognition than non-verbal information. While native speakers had slightly higher recognition scores, the overall pattern observed was very similar for native and non-native speakers. There are a number of possible explanations for why verbal information may have been processed with priority over non-verbal information. Firstly, participants processing may have been biased as a result of experimental instructions. Before viewing the stimuli, participants were told they would be presented with 32 words, with featural alterations made to font type, font colour and spatial letter distribution. Describing the stimuli as words may have prejudiced participants to process them primarily based on their verbal content, rather than the non-verbal dimension. In future studies a more neutral term such as 'items' or 'stimuli' should be used to avoid potential bias. Secondly, interpretation of pictures can be less clear-cut than interpretation of words (Bloom, 2000). As such, there may have been ambiguity about the exact label of a picture. This mislabelling may have included other words deemed equally descriptive of the picture, such as 'pounds' instead of 'banknote', 'woman' instead of 'face' or 'flame' instead of 'fire'. Alternatively, participants might have labelled items on a categorical rather than specific level, such as 'insect' instead of 'dragonfly', 'flower' instead of 'orchid' or 'bird' instead of 'raven'. Thus, non-verbal recognition required a judgement on a more conceptual basis rather than directly comparing identikit detail, such as orthographic composition of words, which could explain longer response latencies. This explanation does not exclude that non-verbal information has an important role to play in stimulus encoding and recognition. Thirdly, the relative roles of verbal and non-verbal aspects in human communication need to be considered. While non-verbal communication is important in conveying supportive information and emotional messages (Grahe & Bernieri, 1999), particularly when it does not match the conveyed verbal message (Argyle, Alkema & Gilmour, 1971), human communication is made unique by the ability to use verbal language (Smith, 2010; Pinker, 1994) and verbalisation is an important tool in making sense of the world that surrounds us (Luria & Yudovich, 1959). With the development of language, verbal aspects of human communication have become more salient (Eskritt & Lee, 2003) and taken a primary role in understanding each other (Rimé, 1982; Rizzolatti & Arbib, 1998). In a similar fashion, non-verbal features used in the current study are mostly of a supportive nature and are unlikely to be entirely meaningful if seen without their verbal counterpart, leading to greater weight and processing priority being assigned to the verbal aspect of items.

Last but not least, learning style needs to be considered as a potential intervening factor (Riding & Douglas, 1993). As such, participants leaning towards a visual learning style may be more inclined to make use of non-verbal information than those more disposed to other types of learning.

General Discussion

The three experiments presented in the present chapter explored both the effect of directed forgetting on integrated stimuli as well as the relative importance of verbal and non-verbal information contained in these items. When tested under free recall conditions in Experiment 9, performance for integrated stimuli was almost indistinguishable from control items with the only difference occurring in native speakers who recalled a greater number of integrated R items. However, examination under recognition conditions in Experiment 10 revealed that integrated stimuli were significantly more recognisable than their standard font counterparts. Thus, with the use of a recognition test, integrated F words performed on the same level as control R words. Further investigation in Experiment 11, comparing verbal and non-verbal recognition performance, revealed that participants found isolated verbal information more recognisable than isolated non-verbal information.

These findings both confirm those obtained in earlier chapters, with native speakers processing integrated stimuli more effectively, and provide additional information about how integrated stimuli are recognised. While integrated items clearly took longer to process than control words, recognition accuracy was significantly improved under both remember and forget instructions when verbal and non-verbal information was combined. In addition, the last experiment revealed that participants focused primarily on verbal information, while recognising non-verbal information with slightly lower accuracy. While this seemingly contradicts the commonly observed recall advantage for pictures over words (Pavio & Csapo, 1973; Lehman et al., 1998), it is likely that this finding is an artefact of the novel and highly unfamiliar stimulus design rather than participants' processing ability of non-verbal information.

Improved performance for native speakers has been observed consistently throughout the current work. This effect has been attributed to the stronger link between objects or concepts and verbal labels in native speakers (da Costa Pinto, 1991). Nevertheless, even native speakers showed more accurate recognition of the verbal than the non-verbal dimensions when these were presented separately at recognition, but as discussed earlier this effect may be a relic of processing the stimuli primarily as language rather than drawings, which in its base function focuses on verbal aspects of communication. Studies have also found that verbalisation of non-verbal material aids both recall and recognition (Kurtz & Hovland, 1953).

The data presented in this chapter also highlight encoding and retrieval processes in relation to integrated stimuli. If the integrated format mostly exerted an effect during retrieval, it would be expected that free recall would result in greater accuracy than recognition since it puts no restriction on retrieval processes. In contrast, if a difference between integrated and control items is established at encoding, recognition tests should lead to greater accuracy since recognition puts less demand on the retrieval system and makes more extensive use of mechanisms used during encoding.

The data presented here show that not only can integrated stimuli perform at the level of standard words in a free recall test, but they can in fact significantly improve recognition, regardless of whether participants are trying to retain them. Thus, under appropriate conditions, items that contain both verbal and non-verbal information in a combined format could significantly enhance item recognition. Although data from Experiment 11 suggest that participants focus on verbal rather than non-verbal information, it is clear from the pattern previously obtained for control items that verbal information alone cannot produce the effect observed here.

While participants may have primarily attended to the verbal dimension, non-verbal information was both processed alongside its verbal counterpart and used to aid recall or recognition of integrated stimuli. The unusual features are also more likely to capture attention due to their distinctive appearance (McDaniel & Einstein, 1986) than standard font words. That is, participants may be more likely to confidently recognise a unique item they have not previously encountered, thus producing a stand-out effect, even when the verbal content itself is familiar. In contrast, recognition of the same word in standard format will trigger more familiar processing mechanisms, this also means that the most recent encounter of the item is more easily confused with past encounters. Furthermore, some participants spontaneously reported being able to recall physical features, but not the verbal content of an item, suggesting that altered features were both encoded successfully and used to aid retrieval. As discussed in earlier chapters, the individual learning style of each participant may have an impact on how integrated stimuli are processed (Riding & Douglas, 1993) with visually orientated learners potentially deriving greater benefit from integrated items than verbally inclined learners (Mayer & Massa, 2003).

In sum, the present chapter assessed integrated and control stimuli under incidental and intentional encoding condition, using either a free recall or recognition test to examine retention rate. Free recall did not reveal retention differences between the two presentation formats, suggesting that it may not have been sensitive to incidental encoding as has been previously suggested (Eagle & Leiter, 1964). For recognition memory, findings revealed that integrated stimuli were significantly more recognisable under both intentional and incidental encoding conditions. This data indicate that non-verbal information was successfully encoded alongside verbal information and aided recognition at retention test. A final experiment was run to determine the relative importance of verbal and non-verbal information in the observed recognition advantage. Results suggested that independently, verbal information was recognised with greater accuracy than non-verbal information. However, when assessing the primary importance of verbal information processing, it should be considered that non-verbal features used are often more ambiguous and more open to interpretation than verbal information. While a picture of a dog may simply be labelled as such by an observer, the terms ‘animal’, ‘mongrel’, ‘canine’, ‘puppy’ or ‘terrier’ may be equally appropriate to describe the picture in question. In turn, the word ‘dog’ does not change as a result of perspective or interpretation and can be easily recognised as referring to the exact same concept on each individual encounter. To test the impact of stimulus ambiguity, the following chapter will endeavour to transfer ambiguity from the non-verbal to the verbal dimension through the use of homonyms, which by their very nature are more ambiguous than words with a single interpretation.

CHAPTER 6

Priming of Homonyms by Altering Word Shape and the Role of Stimulus Ambiguity

Abstract

Findings from Chapter 5 showed that integrated stimuli are recognised more accurately than control words under both incidental and intentional encoding conditions. Results also showed that verbal material was primarily used for recognition, while non-verbal information played a secondary role. Since non-verbal information is commonly more ambiguous than verbal information, the current chapter presents two experiments testing the role of dimensional ambiguity in verbal and non-verbal recognition by using homonyms for initial integrated presentation, which were biased towards either their dominant or subordinate meaning. Experiment 12 used verbal recognition while Experiment 13 employed non-verbal recognition. Reading times of homonyms were not affected by frequency bias during either initial presentation (integrated format) or during either format of recognition (sentence context or labelled picture). Experiment 12 showed reduced effects of frequency bias and enhanced recognition when frequency bias was altered between encoding and recognition. Experiment 13 obtained no effects of frequency bias at all. Results were indicative of holistic conceptual activation, leading to equiprobable recognition of multiple homonym interpretations.

Introduction

Homographs are defined as words with two or more meanings where all separate meanings have identical spelling although pronunciation may differ (e.g. 'tear'). This distinguishes them from both homophones, which show identical pronunciation but different spellings (e.g. 'sun' and 'son') and homonyms, which show both, identical spelling and pronunciation (e.g. 'table' or 'pen'). The distinct meanings usually differ in probability of being accessed as a result of the frequency of use in everyday language, with few showing equiprobable distribution of access likelihood (Rubenstein, Lewis & Rubenstein, 1971). Evidence suggests that each meaning is granted a separate entry in the mental lexicon. Rowe (1973) reports that homonyms presented repeatedly in a section of text were judged as lower frequency occurrence if presented in contexts supporting different meanings than when presented in the same context on every occurrence. These multiple lexicon entries further allow for homographs to be distinguished from non-words faster than words with a singular interpretation (Rubenstein, Garfield & Millikan, 1970), an effect that is particularly pronounced when the possible distinct meanings are not systematically related and are of close to equal probability (Rubenstein et al., 1971). The effect also remains stable when comparing homographs in their low frequency pronunciation with mis-stressed non-homographs and non-words (Small, Simon & Goldberg, 1988). Hereby reaction times for the low frequency pronunciation did not significantly differ from reaction times observed for high frequency pronunciations (Small et al., 1988).

When encountering a homonym, both meanings are initially activated before a decision is reached based on the surrounding context (Elston-Güttler & Friederici, 2005). Studies have found that homographs take longer to read than words with a single meaning and that subordinate meanings typically take longer to access than dominant interpretations (Gottlob, Goldinger, Stone & Van Orden, 1999) even if a disambiguation context is clearly provided (Pacht & Rayner, 1993). If presented in a neutral context, the dominant meaning is always given priority and selected by default (Pacht & Rayner, 1993) and subsequent word recognition is more likely if a context biasing towards the primary meaning is provided (Winograd & Conn, 1971).

When homographs are presented in a clear disambiguating context, the currently irrelevant meaning is suppressed within 200ms and thereafter no longer causes interference (Jones, 1989). Once the appropriate meaning has been selected, other meanings may be inhibited and take longer to process on subsequent encounters (Simpson & Adamopoulos, 2001). However, if the bias towards the subordinate meaning is relatively weak, both meanings may still become activated (Martin, Vu, Kellas & Metcalf, 1999) and it has been found that intrusion is observed from dominant meanings, even if sentence context biases towards the subordinate interpretation (Huab, Zhanga, Zhaoa, Maab, Laib & Yaob, 2011).

While mental representations of homonyms take longer to form than non-homonyms, they are also recalled more accurately in short-term memory (Mashhady, Lotfi & Noura, 2011). Unsurprisingly, research has also shown greater recognition accuracy for homonyms if retrieval cues bias towards the same meaning that was used during initial encoding (McElroy, 1987). Recognition accuracy of dominant meanings is reduced if targets are consequently presented alongside a distractor biasing the subordinate meaning (Kausler & Kamichoff, 1970).

The Role of Native Language

An important dimension of homonym processing is native language. Yu, Xu and Sun (2011) report that greater language proficiency relates to faster disambiguation of homonym meanings, which they theorise may come about as a results of more efficient spreading activation, which occurs as a function of greater proficiency and also comes more easily to native language speakers. Native speakers also show greater accuracy in accessing homonyms when understanding puns or expressions where both meanings are relevant (Burns, 2010). While both native and non-native speakers make use of the same mechanisms for suppressing context inappropriate homonym meanings (Elston-Güttler & Friederici, 2007), non-native speakers use these processes less efficiently in their second language (Elston-Güttler & Friederici, 2005; Frey, 2005) and consequently take longer to achieve successful disambiguation (Elston-Güttler & Friederici, 2007). While subordinate meanings are accessed more slowly in both L1 and L2, the most reliable predictor of speed and accuracy in accessing subordinate meanings in L2 is the speaker's speed and accuracy of subordinate meaning access in L1 (Arêas da Luz Fontes & Schwartz, 2014).

Homonyms can also occur between different languages. Hereby, a distinction is made between noncognates – words with differently spelled translations, such as 'dog' and 'perro', cognates – words with identically spelled translations, such as 'actual' and homographic noncognates – words spelled identically in both languages but with different meanings, such as 'red'. Beauvillain and Granger (1987) suggest that interlexical homographs are activated in a speaker's second language, irrespective of the currently relevant language. Activation likelihood increased if the word frequency is higher in the currently irrelevant language. However, deeper immersion into the relevant language can decrease interference from interlexical homonyms and ensure focus on the currently relevant meaning (Elston-Güttler, Gunter & Kotz, 2005).

The Present Experiments

Results obtained in Chapter 5 suggested that integrated stimuli were processed primarily through a verbal channel, relying more readily on verbal over non-verbal information for correct target identification. Yet, it needs to be considered that while verbal stimuli commonly refer to a single object or concept only, pictures can be more open to interpretation (Bloom, 2000). Words for a specific object remain constant with every use. The word ‘apple’ is always spelled the same way and without fail refers to the same fruit. In contrast, a picture of an apple may vary greatly in aspects of colour, detail and viewpoint. The apple shown could be red, yellow or green, ripe or rotten, viewed from the side or above and could be shown as a simple line drawing or a detailed photograph. Yet all these and many more options are unequivocally described by simply using the word ‘apple’. This makes it at once less informative and more readily recognisable as referring to the same general concept. Equally, a picture showing a handful of coins and banknotes may be described with equal likelihood as ‘money’, ‘change’, ‘payment’, ‘currency’ or the specific currency to which they belong such as pounds or euros, to name but a few. Therefore, while some objects – such as a tree or a chair – may elicit a unanimous label from the majority of people, picture naming is subject to a certain margin of error as a result of the observer’s individual interpretation. With the use of homonyms, however, this effect is somewhat reversed. For verbal stimuli with dual or multiple possible interpretations, picture stimuli are more easily interpreted and offer a more conclusive cue towards target identity than a single word in isolation. That is, reading the word ‘cricket’ is less informative than seeing either a picture of a cricket (the insect) or a picture of a cricket game. In these special cases, pictures can aid disambiguation of verbal stimuli and allow viewers to favour one interpretation over another.

Consequently, the present experiments were devised to test the effect of presenting homonyms in an integrated format, biasing them towards either a high or low frequency context. This design allowed for using verbally ambiguous stimuli, which would be interpreted primarily on the basis of non-verbal rather than verbal features. Thus participants might view the word ‘spade’ either in the shape of a gardening tool or in the shape of the playing card suit as seen in Figure 6.1 below.

Figure 6.1: Example of different integrated presentations of homonym stimuli.

Results will allow additional conclusions to be drawn regarding the relative importance of verbal and non-verbal information and the impact of identifying power of each dimension. If verbal information is given processing priority as a result of greater permanence and therefore more reliable target recognition, the use of pictures for homonym recognition should result in greater accuracy and faster recognition than the use of words, since pictures are better indicators of currently relevant homonym meaning than words. While verbal context will also result in activation of the correct interpretation, pictures have been shown to yield faster access to conceptual information (Paivio, 1971; Stenberg, Radeborg & Hedman, 1995) and are therefore likely to result in faster selection of the correct homonym interpretation. While homonyms are naturally biased towards their highest frequency meaning (Pacht & Rayner, 1993), which is usually activated regardless of current context (Elston-Güttler & Friederici, 2005), the integrated design combining both verbal and non-verbal information might be successful in enabling faster than usual access to low frequency context interpretations and could even go as far as suppressing activation of high frequency context interpretation.

Two experiments were designed. Thirteen homonym pairs were used and presented in integrated format, where physical features biased interpretation towards either the dominant or subordinate meaning of each word. Experiment 12 used verbal recognition, where words were shown embedded in a sentence, while Experiment 13 used non-verbal recognition, where words were shown alongside pictures. A breakdown of the design can be seen in Figure 6.2 below.

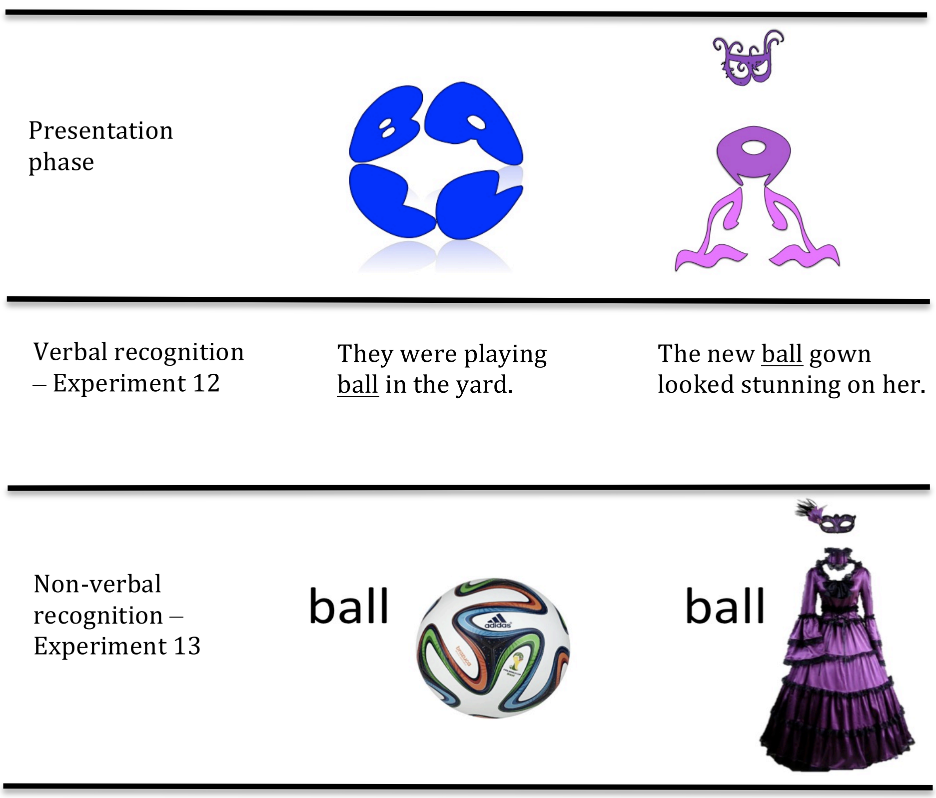

Figure 6.2: Visual map of experimental design in Experiments 12 and 13.

Experiment 12

Experiment 12 was designed to test the effect of manipulating frequency bias through integrated presentation in homonym recognition by means of verbal cueing. Thirteen English homonyms were used and shown in integrated verbal and non-verbal format during presentation, with physical features biasing interpretation towards either the dominant or subordinate meaning of each word. Following presentation, participants were shown the same words in a sentence, where verbal context once more biased interpretation to a dominant or subordinate interpretation. Frequency bias for each stimulus was counterbalanced during both the presentation and recognition phase. Participants then indicated whether or not the word had been shown during the initial presentation phase.

Results from Experiment 11 suggested that verbal recognition is highly accurate and it is expected that this will remain the case despite the innate ambiguity of verbal stimuli in this design. It is further expected that established effects of frequency bias will be observed, with dominant meanings being more readily accessed and more easily recognised. It is also expected that a change of frequency bias between encoding and recognition will result in a deterioration of recognition accuracy. It is further expected that this effect will be more pronounced for native than non-native speakers since they are more practiced in both selecting the context-relevant interpretation of a homonym as well as supressing the currently irrelevant interpretation (Frey, 2005; Elston-Güttler & Friederici, 2005, 2007; Burns, 2010) leading to temporary retrieval inhibition for the supressed interpretation (Simpson & Adamopoulos, 2001).

Methodology

Participants. A total of 57 undergraduate students participated on a voluntary basis. The sample consisted of 32 females (56.1%) and 25 males. Ages ranged from 18 to 56 with a mean age of 22.85 years (SD=5.49 years). More than half of the sample identified themselves as native English speakers (34; 59.6%) while the remaining students spoke English as a second language. Twenty-two participants (38.6%) stated that they had noticed that stimuli were homonyms when asked after having completed the experiment, while the remaining 35 (61.4%) said they had not noticed this during their participation. The majority of the sample was Black (20; 35.1%), followed closely by Asian (19; 33.3%), White (11; 19.3%) and Chinese (3; 5.3%). Two participants each identified themselves as being of either mixed ethnic origin or having other ethnic backgrounds (3.5% each).

Design. The experiment was run as a mixed measures 2x2x2 design. Features compatible with either high or low frequency bias were used at encoding, while sentence context was used to elicit either high or low frequency bias during recognition. Native language was assessed between participants to compare native and non-native speakers. The experiment was split into two phases: initial presentation and recognition. Reaction times and correct scores were recorded during recognition. Reaction times were also recoded during initial exposure to assess potential differences in processing speed between high and low frequency context bias items.

Materials & Apparatus. The experiment was presented on Superlab version 4.0.7b running on Macbook Air with an Intel Core i5 processor (1.7GHz) using OS X

Yosemite. Stimuli were displayed on a 11" flat screen monitor at a resolution of 1366x768px.

A total of 13 English homonyms were used. For a word to be used in the study at least two of its separate meanings had to refer to a physical object which allowed for pictorial representation by using only the letters of the word. Twenty-six stimuli were subsequently created with each homonym being represented twice. Two shape versions of each target were designed; one to bias subjects towards the dominant meaning, while the other biased the subordinate interpretation. For the recognition phase the same homonyms – alongside five distractors, all of which were also homonyms – were presented embedded in a sentence context biasing interpretation either towards the dominant or subordinate meaning. In each sentence the relevant word to which participants needed to respond was underlined.

Procedure. During the initial presentation phase subjects saw a succession of 13 homonyms in which the letters were manipulated to create a pictorial representation designed to bias processing towards either the dominant or subordinate interpretation of the word. Trials were self-paced and reaction times were recorded. Following initial exposure, subjects moved on to the recognition phase where they were shown a total of 18 sentences, 13 containing the target words and 5 distractors. All items were homonyms and sentences were constructed to bias subjects towards either the dominant or subordinate meaning. In addition, subjects would either see targets biased towards the same or a different interpretation as during initial exposure. They were asked to indicate whether or not they had previously seen the word during the presentation phase by pressing either 'Y' or 'N' on the keyboard. After completing the experiment, participants were asked to indicate whether or not they had noticed that all stimuli used were homonyms.

Results

Descriptive statistics displaying means and standard deviations for both dependent variables can be seen in Table 6.1 below.

Table 6.1: Means and standard deviations for recognition times and recognition accuracy for native and non-native speakers across presentation formats.

			recognition times		recognition scores	
			mean	SD	mean	SD
high frequency encoding	high frequency recognition	native speakers	2177.16	1155.15	70.35	27.32
		non-native speakers	2769.76	1712.08	67.22	28.49
	low frequency recognition	native speakers	2633.84	1296.74	79.03	26.31
		non-native speakers	2550.21	1624.25	82.91	27.42
low frequency encoding	high frequency recognition	native speakers	2399.28	1452.97	63.24	29.00
		non-native speakers	2391.58	1176.18	70.43	30.15
	low frequency recognition	native speakers	2205.01	1057.09	59.29	30.04
		non-native speakers	2815.05	2649.52	68.22	27.19

Preliminary chi-square analysis revealed that being a native speaker did not influence the likelihood of noticing that all stimuli were homonyms, $\chi^2(1)=.237$, p=.627. The effect of frequency bias during the presentation phase was also examined with no impact of frequency bias observed during encoding, t(56)=.829, p=.411.

Reaction times. A mixed measures 2x2x2 ANOVA was run, assessing the impact of frequency bias at encoding, frequency bias at recognition and native language on speed of homonym recognition. No significant main effects were observed for encoding, F(3, 55)<1, p=0.604, η_p^2 =0.005, recognition, F(1, 55)<1, p=.0484, η_p^2 =0.009, or native language, F(1, 55)<1, p=0.379, η_p^2 =0.014. No interactions were found between frequency bias at encoding and native language, F(1, 55)<1, p=0.880, η_p^2 =0.023; recognition and native language, F(1, 55)<1, p=0.930, η_p^2 =0.008, or encoding and recognition, F(1, 55)<1, p=0.989, η_p^2 <0.001. A significant three way interaction was observed, F(1, 55)=4.974, p=0.030, η_p^2 = 0.083. These findings are displayed in Figures 6.3 and 6.4 below.

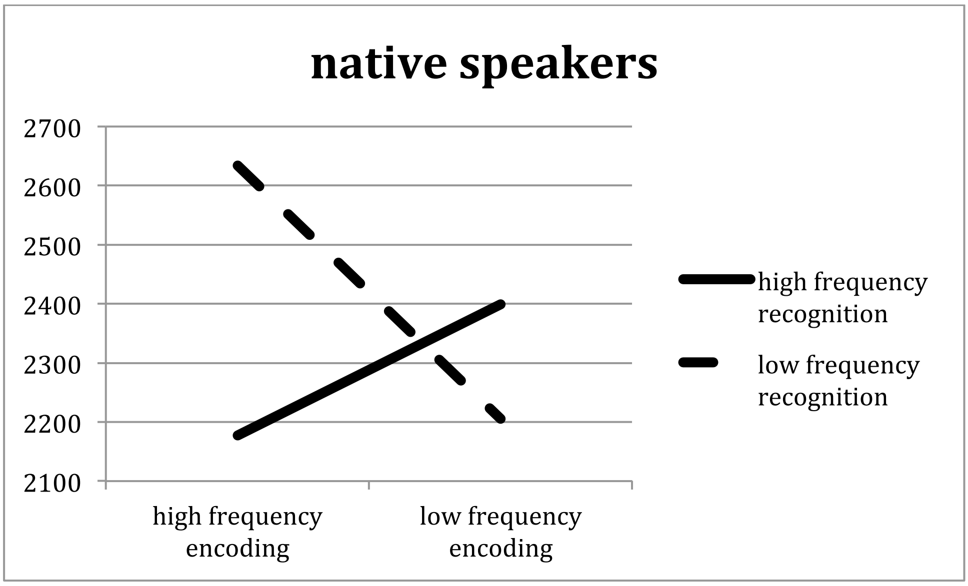

Figure 6.3: Reaction times for native speakers across four conditions following verbal homonym recognition.

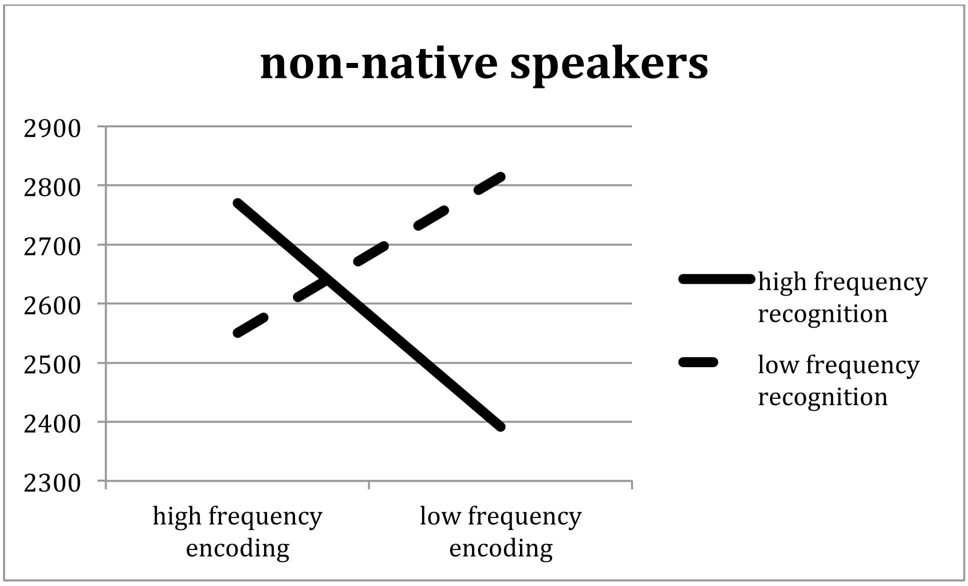

Figure 6.4: Reaction times for non-native speakers across four conditions following verbal homonym recognition.

Subsequent analysis of simple effects revealed that native speakers responded more quickly to stimuli shown in the same frequency bias during both encoding and recognition than to stimuli for which frequency bias was changed, t(33)=2.172, p=0.037. While the opposite trend was observed for non-native speakers, it did not reach significance, t(22)=1.168, p=0.255.

Recognition scores. A mixed measures 2x2x2 ANOVA was run, assessing the impact of frequency bias at encoding, frequency bias at recognition and native language on recognition accuracy. A significant main effect was observed for encoding, F(1, 55)=9.138, p=0.004, η_p^2 =0.142. No significant main effects were observed for recognition, F(1, 55)=1.803, p=.0185, η_p^2 =0.032, or native language, F(1, 55)<1, p=0.426, η_p^2 =0.012. A significant interaction was found between encoding and recognition, F(1, 55)=6.448, p=0.014, η_p^2 =0.105. No interactions were found between frequency bias at encoding and native language, F(1, 55)=1.470, p=0.231, η_p^2 =0.026, or recognition and native language, F(1, 55)<1, p=0.522, η_p^2 =0.007. No significant three way interaction was observed, F(1, 55)<1, p=0.661, η_p^2 = 0.004. Bonferroni post-hoc analysis revealed that stimuli, which were presented in high frequency context during encoding produced highest accuracy than those encoded under a low frequency bias (p=0.004). In particular, native speakers showed more accurate recognition for words encoded under a high frequency bias (p=0.002), while non-native speakers showed no difference in processing as a result of frequency bias during encoding (p=0.246). Furthermore, stimuli recognised under a low frequency bias were recognised more accurately when also presented with a low frequency bias during encoding (p<0.001); no such effect was found for stimuli with a high frequency bias (p=0.647). In contrast, stimuli encoded with a high frequency bias were recognised more accurately when presented with a low frequency bias during recognition (p=0.013). These results are shown in Figures 6.5 and 6.6 below.

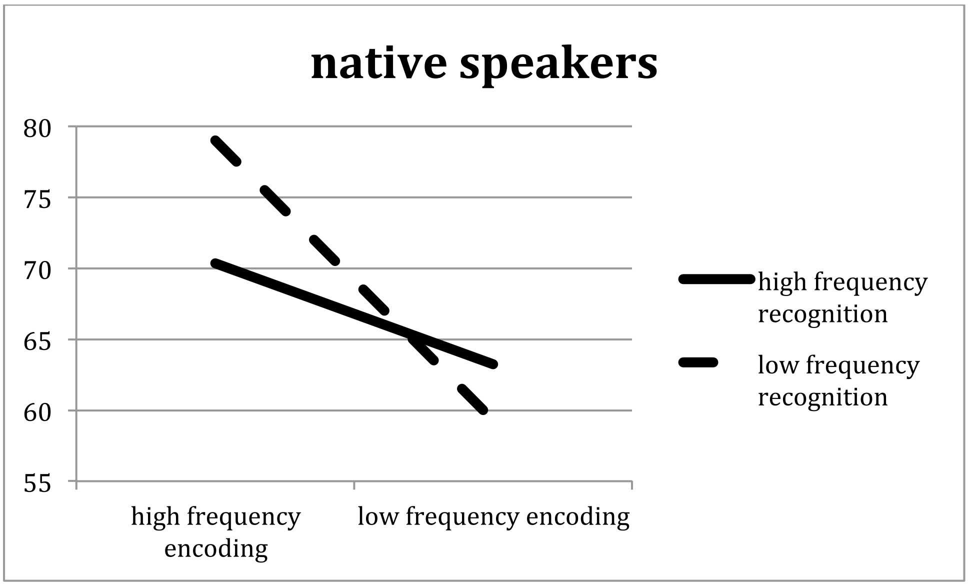

Figure 6.5: Recognition accuracy for native speakers across four conditions following verbal homonym recognition.

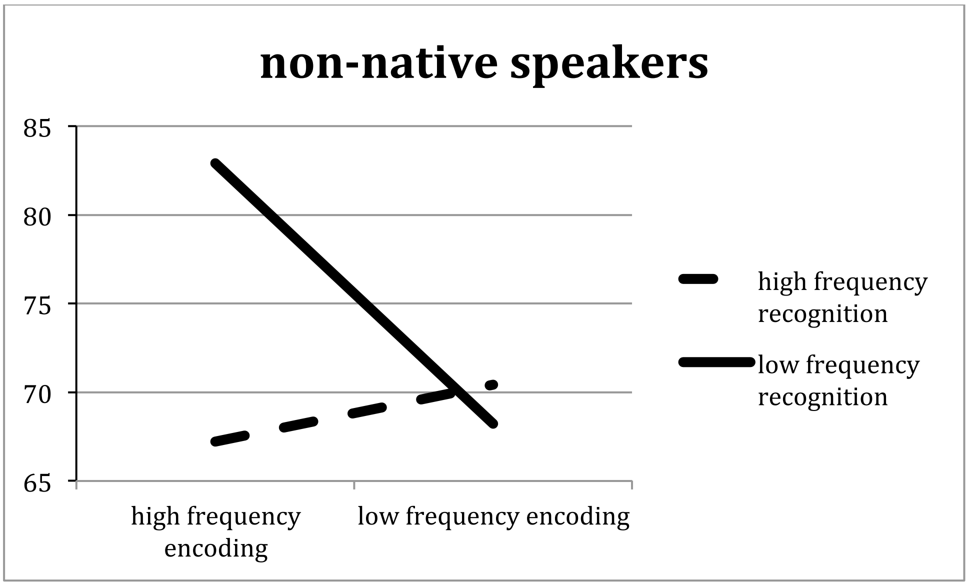

Figure 6.6: Recognition accuracy for non-native speakers across four conditions following verbal homonym recognition.

Discussion

Experiment 12 was designed to assess the effect of manipulating frequency bias through integrated presentation in homonym recognition by means of verbal cueing. Stimuli biased towards both a high and low frequency interpretation were recognised equally quickly, suggesting that integrated stimuli did allow faster and more direct conceptual access to the relevant interpretation since subordinate meanings have previously been found to yield slower response latencies (Gottlob et al., 1999). Alternatively, it is possible that small differences in response times may have been clouded by the long response latencies observed as a result of the unfamiliar presentation format.

No effect of frequency bias manipulation on reaction times was detected on the overall sample. However, when reaction times for native and non-native speakers were analysed separately, it emerged that native speakers responded faster to stimuli where the frequency bias remained constant than to those where it was changed between encoding and recognition. This is in accordance with findings presented by Simpson and Adamopoulos (2001) suggesting that native speakers are more skilled at homonym disambiguation and temporary suppression of irrelevant interpretations (also see Elston-Güttler & Friederici, 2005, 2007). No effect of altering frequency bias was found for non-native speakers. It is likely that while native speakers process words primarily on a semantic level, non-native speakers may have a more lexical focus on words, before fully accessing word meaning, therefore being less susceptible to inhibition of an irrelevant interpretation and placing greater focus on the orthographic nature of a word than would be expected from native speakers.

When analysing recognition accuracy scores, however, a more pronounced picture emerged. As in Experiment 11, encoding processes appeared to play a greater role than retrieval, with no difference being observed between presenting words in high or low frequency context during recognition, but a significant effect was obtained for varying high and low frequency context during the encoding phase. That is, while stimuli were recognised equally accurately regardless of frequency bias used during the recognition phase, stimuli encoded under a high frequency bias were recognised with greater accuracy, regardless of whether they were biased towards the same or a different context during recognition. Contrary to expectation, stimuli for which the frequency bias changed between encoding and recognition phase were recognised with greater accuracy than those where the frequency bias remained constant. However, looking at the distribution of scores across conditions, this effect may have occurred as an artefact of highly accurate recognition for stimuli encoded under a high frequency bias, rather than as a result of the frequency bias alteration. Alternatively, a conceivable explanation could lie in the nature of the integrated stimuli. It is possible that instead of strengthening the bias towards one interpretation over another, their unfamiliar nature may encourage more extensive stimulus processing on a general scale, resulting in enhanced activation of both possible homonym interpretations. Alternatively, it is possible that the longer reading times resulting from the unfamiliar presentation format of integrated stimuli may have extended processing time to allow full activation of both interpretations. Finally, participants may not have processed the non-verbal information accurately and non-verbal features could have been perceived as ambiguous, resulting in dual homonym activation.

Experiment 13

Experiment 13 was designed to test homonym recognition in non-verbal format. The use of images instead of sentence cues should result in faster activation of the relevant homonym interpretation, leading to reduced ambiguity during recognition, since pictures would allow direct conceptual access to a single interpretation. Verbal labels were also included alongside images to ensure accurate picture naming. The use of both verbal and non-verbal information during recognition is also likely to more closely reflect the initial encoding format. While findings obtained from Experiment 11 suggested that recognition accuracy was based primarily on verbal information, verbal stimuli used were unambiguous and could be reliably recognised as referring to the same concept. Since the opposite is true of homonyms, biasing homonym interpretation by using picture stimuli should result in faster and more accurate activation of the currently relevant meaning (Stenberg, Radeborg & Hedman, 1995) and reduce the chance of dual meaning activation.

Findings from Experiment 12 revealed some of the expected effects of manipulating frequency bias. Homonyms biased towards their dominant meaning during encoding were recognised faster and more accurately, while manipulation of frequency bias during recognition had no effect. Equally, a reverse effect of varying frequency bias between encoding and retrieval was observed on recognition accuracy, contrary to what would have been expected if integrated stimuli were successful in eliciting a strong encoding bias towards one interpretation over the other. As discussed above, it is conceivable that instead of merely activating the interpretation towards which they are biased, integrated stimuli encourage more holistic processing on a wider scale, leading to more complete activation of both dominant and subordinate interpretations alike. If integrated stimuli result in exclusive activation of a single homonym interpretation, there should be a marked difference between items for which frequency bias is changed between encoding and recognition and items where frequency bias remains constant, with the latter showing shorter response latencies and higher accuracy. If, on the other hand, integrated stimuli result in equal activation of both interpretations, no effect as a result of manipulating frequency bias should be observed.

Methodology

Participants. A total of 40 undergraduate students participated in the experiment. The sample consisted of 22 females (55%) and 18 males. Ages ranged from 18 to 52 with a mean age of 24.98 years (SD=8.19 years). More than half of the sample identified themselves as native English speakers (26; 65%) while the remaining students spoke English as a second language. Twenty-seven participants (67.5%) stated that they had noticed that stimuli were homonyms when asked after having completed the experiment, while the remaining 13 (32.5%) said they had not noticed this during their participation. The majority of the sample was White (22;

55%), followed by Black (8; 20%), Asian (5; 12.5%) and Chinese (2; 5%). Two participants identified themselves as being of mixed ethnic origin and one listed other ethnic backgrounds.

Design. The design for the presentation phase was identical to Experiment 12. In order to induce frequency bias during recognition, pictures instead of sentences were used.

Materials & Apparatus. The apparatus used as well as the stimuli for the presentation phase were identical to Experiment 12. In contrast to the previous experiment, homonyms were shown alongside pictures biasing interpretation towards either the dominant or subordinate word meaning during the recognition phase.

Procedure. The procedure followed that of Experiment 12, but during the recognition phase, participants viewed each homonym alongside a picture rather than being presented in a sentence context. No other changes to the procedure were made.

Results

Descriptive statistics displaying means and standard deviations for both dependent variables can be seen in Table 6.2 below.

Table 6.2: Means and standard deviations for recognition times and recognition accuracy for native and non-native speakers across presentation formats.

			recognition times		**recognition scores**	
			mean	**SD**	**mean**	**SD**
high frequency	high frequency	native speakers	1578.21	666.18	75.42	22.83

encoding	recognition	non-native speakers	1811.63	823.24	70.00	27.84
	low frequency recognition	native speakers	1904.10	872.65	77.62	22.27
		non-native speakers	1868.34	861.34	61.14	36.63
low frequency encoding	high frequency recognition	native speakers	2073.07	1374.88	69.27	22.96
		non-native speakers	1910.69	939.20	62.93	34.29
	low frequency recognition	native speakers	2103.11	1308.30	69.88	28.28
		non-native speakers	1880.65	647.84	65.29	26.78

Preliminary chi-square analysis revealed that being a native speaker did not influence the likelihood of noticing that all stimuli were homonyms, $\chi^2(1)=.152$, $p=.697$. The effect of frequency bias during the presentation phase was also examined with no impact of frequency bias observed during encoding, $t(39)=-.870$, $p=.389$.

Reaction times. A mixed measures 2x2x2 ANOVA was run, assessing the impact of frequency bias at encoding, frequency bias at recognition and native language on speed of homonym recognition. No significant main effects were observed for encoding, $F(3, 38)<1$, $p=0.401$, $\eta_p^2=0.019$, recognition, $F(1, 38)<1$, $p=.832$, $\eta_p^2=0.001$, or native language, $F(1, 38)=2.592$, $p=0.116$, $\eta_p^2=0.064$. No interactions were found between frequency bias at encoding and native language, F(1, 38)<1, p=0.583, η_p^2 =0.008; recognition and native language, F(1, 38)<1, p=0.592, η_p^2 =0.008, or encoding and recognition, F(1, 38)<1, p=0.471, η_p^2 <0.014. No significant three way interaction was observed, F(1, 38)<1, p=0.340, η_p^2 = 0.024. These findings are displayed in Figures 6.7 and 6.8 below.

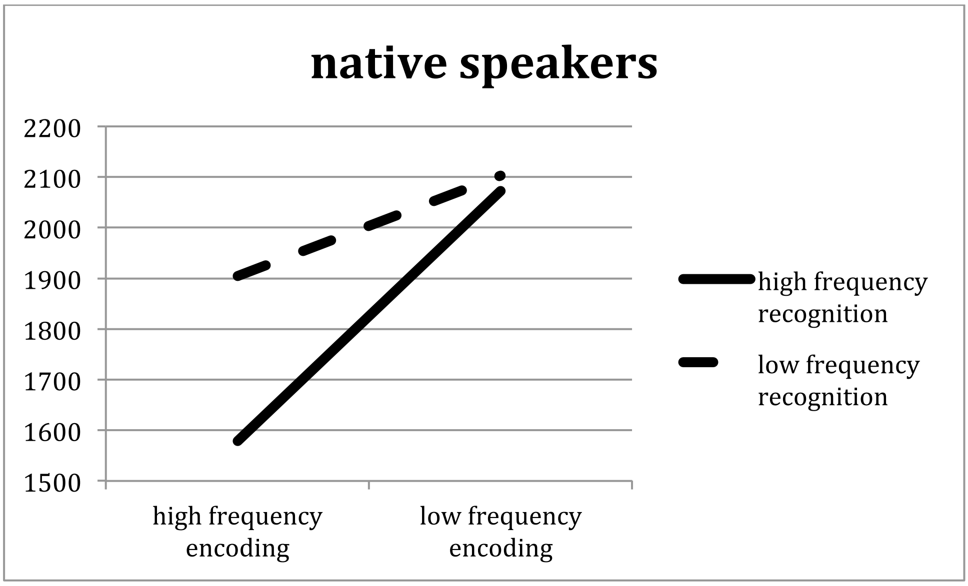

Figure 6.7: Reaction times for native speakers across four conditions following non-verbal homonym recognition.

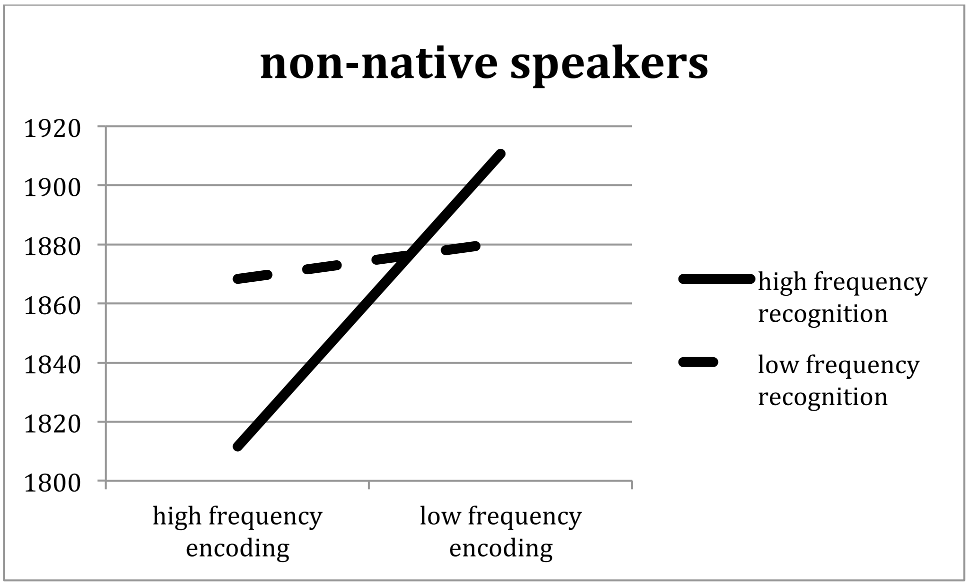

Figure 6.8: Reaction times for non-native speakers across four conditions following non-verbal homonym recognition.

Recognition scores. A mixed measures 2x2x2 ANOVA was run, assessing the impact of frequency bias at encoding, frequency bias at recognition and native language on speed of homonym recognition. No significant main effects were observed for encoding, $F(3, 38)<1$, $p=0.401$, $\eta_p^2=0.019$, recognition, $F(1, 38)<1$, $p=.832$, $\eta_p^2=0.001$, or native language, $F(1, 38)=2.592$, $p=0.116$, $\eta_p^2=0.064$. No interactions were found between frequency bias at encoding and native language, $F(1, 38)<1$, $p=0.583$, $\eta_p^2=0.008$; recognition and native language, $F(1, 38)<1$, $p=0.592$, $\eta_p^2=0.008$, or encoding and recognition, $F(1, 38)<1$, $p=0.471$, $\eta_p^2<0.014$. No significant three way interaction was observed, $F(1, 38)<1$, $p=0.340$, $\eta_p^2= 0.024$. These findings are displayed in Figures 6.9 and 6.10 below.

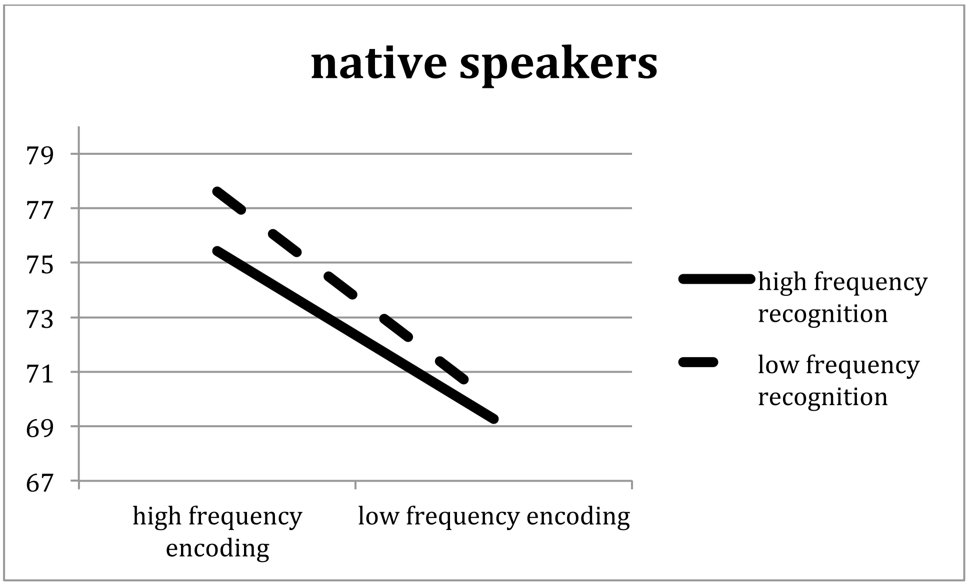

Figure 6.9: Recognition accuracy for native speakers across four conditions following non-verbal homonym recognition.

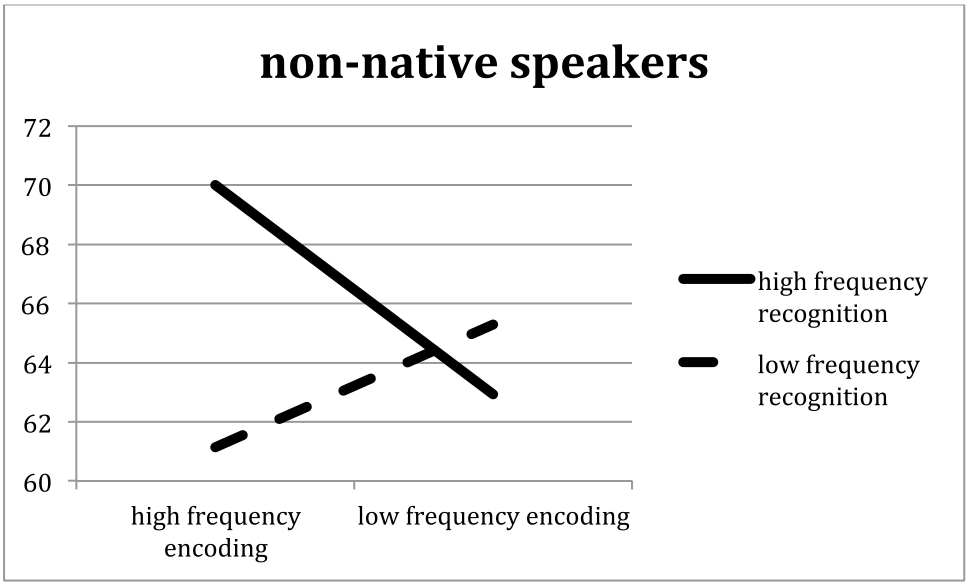

Figure 6.10: Recognition accuracy for non-native speakers across four conditions following non-verbal homonym recognition.

Discussion

Experiment 13 was designed to assess the effect of varying frequency bias through the use of integrated stimuli on homonym recognition by means of non-verbal cueing. It also allowed assessment of the impact of non-verbal cueing in integrated stimuli where stimulus ambiguity was transferred from the non-verbal to the verbal dimension. No significant impact of manipulating frequency bias was found for either reaction times or response accuracy in the current experiment.

It was expected that frequency effects would be more pronounced if integrated stimuli were successful at evoking a stronger mental image, leading to increased activation of the current frequency bias and more effective suppression of the currently irrelevant interpretation. Yet, data failed to support this hypothesis. Instead, the results suggest that rather than restricting homonym processing to a single, currently relevant entry in the mental lexicon, the combined use of verbal and non-verbal information results in more complete, holistic activation of a full stimulus representation which stretches to activation of multiple interpretations for homonyms. It appears that homonyms benefitted from dual activation of both dominant and subordinate interpretations – possibly as a result of deeper processing – eliminating the impact of manipulating frequency bias as a result. Activating both possible homonym interpretations would allow recognition through two possible routes, where either interpretation could be used a cue to recognition. This resulted in faster response latencies than under verbal cueing conditions, since both entries to the mental lexicon can be accessed with equal likelihood and either interpretation has the potential to yield a positive recognition response. Integrated stimuli were theorised to have the potential for holistic conceptual activation and the current results indicate that additional activational mechanisms were involved in processing integrated stimuli. With equiprobable activation for either homonym interpretation observed in the current study, it is clear that integrated items do not subscribe to traditional processing patterns. This effect could have readily occurred as a result of the enhanced presentation format, which was designed to encourage full stimulus processing. Although stimulus design was intended to only activate a single homonym interpretation, participant responses clearly indicated that both interpretations were activated during processing. Since the integrated presentation format resulted in longer reading times, it is also possible that the resulting additional exposure allowed a more complete conceptual activation, which could explain why dual interpretations were activated for homonym processing rather than enhanced activation of a single interpretation and suppression of the irrelevant meaning.

A potential criticism could be raised regarding the design of non-verbal cueing. While pictures were displayed in a prominent position, verbal labels were also included, effectively resulting in a mixture of both verbal and non-verbal cueing. Yet, the inclusion of verbal labels is essential as images are unlikely to be unanimously named, which would result in primary ambiguity being transferred once more to the non-verbal dimension. Not all participants may be familiar with the physical characteristics of, for instance, a cricket and could easily confuse it with a grasshopper or another insect, entirely defeating the purpose of cueing. Nevertheless, they are likely to recognise the image as a cricket if it carries the appropriate verbal label. Furthermore, the differences in results obtained compared to Experiment 12 suggest that non-verbal cues did elicit a significant impact on the recognition processes.

General Discussion

The two experiments presented here focused on the role of verbal and non-verbal information in recognition, when primary stimulus ambiguity occurred in the verbal rather than non-verbal dimension. Commonly, pictures are more open to interpretation than words (Bloom, 2000) and the current chapter aimed to investigate circumstances under which ambiguity was shifted from the non-verbal to the verbal dimension. To test this, homonyms were used as stimuli whose interpretation is by their very nature ambiguous since they can refer to two – or more – often radically different concepts.

Homonym recognition accuracy was recorded at approximately seventy percent and was substantially higher than in previous experiments where recall rates ranged between five and forty percent, while recognition rates varied between ten and twenty percent. Masshady, Lotfi and Noura (2001) found that while homonyms take longer to access they are also recalled more accurately in short-term memory. This is further confirmed by longer initial reading than subsequent recognition times, although part of this delay may have occurred as a result of the unfamiliar presentation format (Ahlén, Hills, Hanif, Rubino & Barton, 2014). In addition, recognition under non-verbal cueing conditions was significantly faster than recognition under verbal cueing conditions, which was expected if superior verbal recognition in Experiment 11 occurred as a result of non-verbal stimulus ambiguity. Picture stimuli were processed faster although verbal stimuli, too, were designed to eliminate interpretation uncertainty. This confirms the suggestions that pictures allow faster access to semantic information than words (Park, 1980; Paivio, 1971, 1986) as well as the paramount role of stimulus ambiguity. However, it should also be considered that the relative position of the to be recognised word within the sentence context used in

Experiment 12 may have played a role in the speed with which disambiguation of meaning was achieved. Semantically related words occurring prior to the stimulus in question (e.g. 'The sheep were kept inside their pen.' or 'He picked up a piece of paper and a pen.') would prime one interpretation over the other and lead to faster disambiguation when the target word is reached. If, in contrast, the disambiguating context words occur following the target stimulus, both possible meanings may be initially activated before the relevant interpretation is selected (e.g. 'The ball bounced across the courtyard.' or 'The ball would be held at the town hall.').

While Experiment 11 highlighted the impact of encoding, Experiments 12 and 13 add to the importance of retrieval processes, particularly when verbal stimuli show interpretation ambiguity. While the use of combined verbal and non-verbal cueing reduces ambiguity in both words and pictures alike, single interpretation verbal stimuli are more successful in reducing picture ambiguity, whereas non-verbal cues are more effective in eliminating ambiguity in homonyms. The findings suggest that using both verbal and non-verbal information in combination leads to more holistic conceptual activation to the extent that multiple potential interpretations of homonyms can be activated to achieve equiprobable access likelihood.

In sum, the present chapter tested the role of ambiguity in successful recognition of integrated verbal and non-verbal stimuli on the basis of only a single dimension. Results indicated that recognition is based on the least ambiguous information. While Experiment 11 indicated longer response latencies for picture recognition, the current chapter found that when the verbal dimension was associated with greater ambiguity, faster responses were observed for non-verbal recognition cues. Findings also suggest that integrated stimuli lead to holistic conceptual activation of homonym, resulting in equal availability of both possible interpretations as expressed in the lack of frequency effects when frequency bias was altered between encoding and recognition.

The primary aim of the current body of work was the development of a new presentation format, which would allow holistic conceptual activation of concrete stimuli. While processing differences in integrated items emerged from an early stage in the research, no recall advantages were observed for these items. Eventually, a recognition advantage emerged, independent of encoding intention. Yet, it is only in the current chapter that evidence of holistic processing was obtained. The equiprobable activation of either homonym interpretation in the final experiment is indicative of holistic processing which exceeds the strict limits of the visually presented material.

The final chapter will summarise the findings and interpret them in light of previous research and existing theories. Finally, implications of results as well as possible applications and potential uses of these items will be explored and discussed alongside directions for future research.

CHAPTER 7

General Discussion

Abstract

The final chapter begins by summarising the findings obtained and offering an overview of the data. The second section highlights the findings in a more general context and endeavours to explain them in relation to earlier theories and research to put results in a wider theoretical context. Subsequently, possible applications of the findings are discussed and how results might be interpreted and employed in a more practical framework. Finally, limitations are discussed and future research directions are suggested to follow up on questions, which are currently left unanswered and would benefit from further experimental investigation.

Summary of Findings

It was the premise of the current work that processing efficiency as well as retention accuracy could be improved through the use of fully visually integrated verbal and non-verbal information. To test this proposition, a large set of novel stimuli was developed which incorporated both a verbal and non-verbal dimension into a single visual object by means of utilising individual letters to form a global shape.

Experiment 1 used the traditional approach of comparing word and picture stimuli separately but also added two combined dimensions; one in which verbal and non-verbal information were visually separated and one where the two types of information were fully integrated into a single stimulus, adding up to a total of four independent conditions. Incidental memory was tested and a categorisation task – where each item had to be identified as either natural or man-made – was administered to keep participants unaware of a subsequent free recall test. Reaction times were unusually slow and proved largely uninformative. No overall differences in response times were observed, although native speakers processed fully integrated stimuli faster than non-native speakers. Recall scores revealed that separated stimuli containing both verbal and non-verbal information were recalled with the greatest accuracy, providing some support for dual coding theory (Paivio, 1971, 1986, 1991). On the other hand, a series of commonly observed effects, namely the picture superiority effect (Shepard, 1967; Blanc-Brude & Scapin, 200; Stenberg, Radeborg & Hedman, 1995; Mitchell, 2006) as well as a positive correlation between exposure time and recall likelihood (Loftus & Kallman, 1979; Potter, 1976; Potter & Levy, 1969; Tversky & Sherman, 1975) were not detected in this experiment. One possible explanation could have been found in the nature of the distractor task, which may have obscured other effects as a result of presentation format. Consequently, Experiment 2 omitted the distractor task in favour of read only instructions, while conditions and stimuli remained unchanged. Participants remained unaware of the recall test. As a result of omitting the distractor task, overall recall performance increased for all types of stimuli. Response times were still slow and no significant differences were observed, although native speakers once more outperformed non-native speakers on recall of integrated stimuli. In addition, while correlations between exposure time and recall likelihood now emerged for words, pictures and separated stimuli, no correlation was observed for integrated items, suggesting that different mechanisms were involved in encoding and retrieval of integrated items. Pictures also showed highest recall rates in this design, in line with previous results (Shepard, 1967; Stenberg, Radeborg & Hedman, 1995; Mitchell, 2006). The overall pattern of results suggested that processing of integrated stimuli most closely resembled picture processing.

Since omission of the distractor task yielded results more commonly observed in the literature, experiments described in Chapter 3 further simplified the experimental task and exchanged more complex stimuli for simple geometric shapes. Two experiments were designed to investigate the role of dimensional integration in a shape Stroop task (Stroop, 1935, Hentschel, 1973; Flowers and Stoup, 1977). Experiment 3 used separated stimuli where words were presented inside shape outlines. So-called 'attentional control settings' were manipulated and participants responded to words in half the trials and shapes in the other half. Faster response times were observed for congruent trials, where shape and word matched, but further analysis revealed that this effect remained significant for shape control settings only. No effects of varying congruency or control setting were observed on error rates. Experiment 4 subsequently repeated the design, using integrated stimuli where shape words were written in either congruent or incongruent shapes. Control setting had no impact on response times, but congruent trials yielded faster responses than incongruent trials. Error rates now showed significantly higher accuracy for congruent over incongruent trials. In addition, comparison of all data collapsed across Experiments 3 and 4 revealed that word control settings in congruent trials yielded higher accuracy in integrated over separated trials, while congruency benefited shape control setting regardless of integration. Findings indicated that integration of verbal and non-verbal information was achieved successfully, with dimensions processed as a single item as indicated by equiprobable attentional capture from either dimension in fully integrated trials.

Chapter 4 retained the manipulation of congruency as a study variable but with integration of verbal and non-verbal information achieved successfully, reverted back to the use of more complex stimuli rather than basic shapes. Experiment 5 compared two types of integrated stimuli – congruent and incongruent – where shapes either did or did not match the word, with control stimuli written in standard font. Presentation formats were blocked in a repeated measures design to test the effect of dimensional congruency in more complex integrated stimuli. As in Experiment 1 a sorting task was given to test incidental recall. Control words were processed faster than both types of integrated stimuli but no effect of presentation format on recall scores was observed. Native language did not exert an effect. Following the steps taken in Chapter 1, the distractor task was omitted for Experiment 6 and incidental recall was tested under read only instructions with trial duration set at 2000ms to eliminate any impact of exposure time. Recall scores were not affected by the restricted exposure time and no effect of presentation format was observed. Since no significant results were obtained under incidental encoding conditions, Experiment 7 tested intentional recall. Trial duration remained fixed at 2000ms and the same stimuli were used as in the previous two studies. Under intentional encoding conditions, only incongruent stimuli were outperformed by control items, while congruent items did not differ either from control or incongruent stimuli. When analysed separately, native speakers showed no recall difference between congruent and control stimuli. An interaction was observed between presentation format and native language. Simple effects revealed a non-significant trend for native speakers to recall more congruent than control items with the reverse pattern occurring for non-native speakers. Despite making participants aware of the recall test, recall was still low with less than 30% of words recalled accurately. To address this, as well as to allow additional processing time for integrated stimuli, exposure times were extended to 4000ms in Experiment 8. While recall rates improved, the increase was small with an average of one additional word recalled in each condition. The resulting pattern of results was highly similar to Experiment 7; control words were recalled better than incongruent items, while congruent stimuli did not differ from either incongruent or control items. The interaction between presentation format and native language was no longer significant, although a small trend remained. This may indicate that longer exposure times allowed non-native speakers the additional processing time needed to match performance of native speakers.

While both incidental and intentional memory had been tested so far, only free recall tests had been administered. However, Eagle and Leiter (1964) suggested that while intentional encoding is best tested through free recall, incidental memory is more accurately tested through recognition. Consequently, Chapter 5 explored incidental and intentional encoding mechanisms in direct comparison through the use of directed forgetting instructions. Congruency was omitted as a variable and only congruent integrated and control stimuli were used. To allow additional processing time for complying with encoding instructions, trials were now fixed at 3000ms. Experiment 9 presented both integrated and control words. For each stimulus participants were instructed to either remember or forget the item. Subsequently, a free recall test was administered. Effects were observed for encoding cue and native language, but not presentation format. To be remembered items outperformed to be forgotten items for both presentation formats and native speakers recalled a greater number of items than non-native speakers independent of presentation format. In turn, Experiment 10 presented the same stimuli under the same encoding conditions, but tested retention by using a recognition test. Recognition times were recorded but no significant effect of any of the variables on response latencies was observed. Recognition accuracy was significantly affected by encoding cue and presentation format, but not native language. To be remembered items were recognised more accurately. Correlational results between recognition speed and accuracy indicated incomplete encoding of integrated stimuli under both encoding conditions, leading to uncertainty during response selection. Nevertheless, results established a significant recognition advantage for integrated stimuli regardless of encoding instructions. Since integrated stimuli contain both verbal and non-verbal information, Experiment 11 was designed to determine which dimension is predominantly used for recognition. All stimuli were now presented in integrated format and participants were instructed to either remember or forget each item. During recognition, items were now presented as either words or pictures. A significant response time effect was observed for recognition format, while encoding cue and native language did not exert an impact. Words were responded to faster than pictures. Recognition accuracy was significantly affected by encoding cue and recognition format, but not native language. As before, to be remembered items were recognised more accurately than to be forgotten items and recognition was more accurate for words than pictures. The findings indicate the primary use of verbal information in recognition processes. However, it is also clear that word only stimuli cannot yield the same recognition accuracy as integrated stimuli.

Although findings from Chapter 5 indicated that verbal information was encoded more fully than non-verbal information, verbal stimuli are commonly less ambiguous than non-verbal stimuli. The word 'flower' is always spelled 'flower', while images of a flower could vary widely and elicit a number of different labels ranging from specific descriptors like 'daisy' or 'rose' to more general words like 'plant' or 'blossom'. To test the impact on ambiguity, Chapter 6 used homonyms, where greater uncertainty would be associated with words rather than pictures. The word 'pen' may refer either to a writing implement or an animal enclosure, where as pictures of either object would be unambiguous. Thus, while homonyms need context to activate their correct meaning, either meaning can be unequivocally communicated in a picture. Experiment 12 used thirteen English homonyms presented in integrated format designed to bias interpretation towards either their dominant or subordinate interpretation. Recognition was based on verbal context through the use of sentences.

Encoding under high frequency bias yielded better recognition than low frequency bias encoding, while frequency bias during recognition had no impact. Contrary to previous literature, stimuli for which frequency bias was changed between encoding and recognition were recognised with higher accuracy than trials where frequency bias remained constant. No impact of frequency bias was observed on response times either during encoding or recognition. In turn, Experiment 13 used non-verbal recognition, biasing interpretation through the use of pictures. In this instance, no significant effects were observed for either recognition times or accuracy, with frequency bias eliciting no impact. The findings indicate that integration of verbal and non-verbal information aids holistic processing, leading to full homonym activation including increased semantic access to multiple interpretations, rather than merely strengthening a single interpretation.

Findings in Relation to Previous Literature

Findings obtained in this work both confirm previous theories and offer new insight into the processing of verbal and non-verbal information and in particular the role of feature integration. Results provide evidence for dual coding (Experiment 1), picture superiority (Experiment 2), the Stroop effect, as well as the interaction between feature integration and attentional control settings (Experiments 3, 4), the role of dimensional congruence (Experiments 3-8), the effects of encoding instructions (Experiments 5-8) and exposure time (Experiments 2, 7, 8), directed forgetting and the interaction between encoding mechanisms and recall test (Experiments 9-10), the role of verbal and non-verbal information in recognition (Experiment 11) and the impact of stimulus ambiguity (Experiments 12, 13).

Throughout the experiments, the impact of native language was also observed repeatedly.

Experiment 1 suggested that when no effort is made to retain presented material, presentation of both verbal and non-verbal information in separate visual locations can aid recall and may trigger dual coding mechanisms (Paivio, 1971, 1986, 1991), leading to superior information retention. The experiment also confirmed faster semantic access for picture stimuli as indicated by faster categorisation times (Glaser & Glaser, 1989; Blanc-Brude & Scapin, 2007; Seifert, 1997). In addition, findings highlighted the potential confounding effect of administering a distractor task (Noldy, Stelmack & Campbell, 1990), leading to the dilution even of well-established phenomena. With omission of the distractor task, Experiment 2 revealed a pattern of superior picture processing as has often been observed in previous studies (Paivio & Csapo, 1973; Stenberg, Radeborg & Hedman, 1995). With view only instructions and the potential for anticipating a recall test without being explicitly aware of it, pictures were now recalled better than either words or a combination of verbal and non-verbal material. Neither fully integrated stimuli, nor the very same images accompanied by their verbal labels derived a similar benefit. These results may indicate that the retention advantage for pictures does not merely arise from the pictures themselves but could also be associated with the absence of verbal information or the need to effortfully retrieve it. Alternatively, language theorists have suggested that while language has become an essential tool in human communication, its impact on thought can be restrictive as well as helping to express it (Bloom, 2000; Pinker, 1994). Thus, it is possible that pure picture stimuli are processed through a more abstract channel and are not necessarily translated into the verbal dimension at all. Yet, when a verbal label is forcibly applied, this free form of processing may be hindered and retention likelihood could decrease. Further investigation into this area could help increase understanding of verbal and non-verbal processing pathways.

Experiments 3 and 4 followed the traditional Stroop paradigm, using shapes rather than colours to represent the non-verbal dimension. Congruence showed significant effects regardless of integration and control setting, but was more pronounced for shape control setting and integrated stimuli. This is in line with previous findings both regarding the basic pattern of the Stroop effect (Stroop, 1935; MacLeod, 1991) as well as theories and findings regarding feature integration (Treisman & Gelade, 1980; Wolfe, Cave & Franzel, 1989; Tsal, 1989; Prinzmetal, 1995). In separated trials, although congruent stimuli yielded faster response latencies, error rates were unaffected. This pattern has commonly been observed in similar studies (Hentschel, 1973; Flowers & Stoup, 1977; MacLeod, 1991). Error rates have generally received less attention in Stroop task experiments, with the primary focus being placed on response latencies (MacLeod, 1991). This generally occurs since error rates tend to be low and often do not show the same sensitivity as response times. However, Experiment 4 revealed that with fully integrated stimuli, error rates were affected by congruency manipulation and both the traditional (Stroop, 1935) and reverse (Stroop, 1935; Blais & Besner, 2006; 2007) Stroop effects were observed for both response times and accuracy. Although in the traditional colour/colour-word task dimensions are also fully integrated, reverse interference is not commonly detected (Durgin, 2000; 2003); that is, ink colour does not usually affect speed or accuracy of colour word reading. Of course, text is often encountered in different colour prints, where ink colour does not relate meaningfully to content or meaning and can therefore be largely ignored as a diagnostic property.

The use of control settings was essential in determining the impact of integration. Altering control settings between trials highlighted the clear differences in results between separated and integrated stimuli and evidenced that dimensional integration was successful. While control settings generated a significant effect in separated trials resulting in a congruence effect being observed for shape responses only, both shape and word responses yielded significant effects of congruence in integrated trials. Results for integrated trials indicated that both dimensions were processed as a holistic object rather than two separate entities occupying the same visual space (Duncan, 1984). This also indicates that although attentional control settings may be tuned to a particular feature, attention will automatically be allocated to other features of the same visual object when the sought after detail is successfully detected, while the same is not true for nearby or surrounding objects.

Results from Chapter 3 highlighted the impact of dimensional congruence and the effect was explored in more complex stimuli in Chapter 4. While the effect of congruence appeared less pronounced, it was nevertheless clear that while congruent features were processed and understood successfully, similar to standard words, incongruent features could be a hindrance to successful stimulus processing (Garner, 1976; Prinzmetal, 1995). Results indicated that congruence between verbal and non-verbal material leads to more successful conceptual activation, with a particular advantage observed for native speakers. While congruent pictorial features could activate a feedback loop between verbal and non-verbal material, leading to mutual cueing, incongruent features would have been either irrelevant to or hindered stimulus processing (Garner, 1976; Prinzmetal, 1995). In addition, the role of encoding instructions was examined. While little or no difference was observed in incidental encoding, intentional encoding conditions amplified the existing processing differences and revealed that unlike incongruent stimuli, congruent items did not significantly differ from control items in their level of memorability and could even produce a small benefit for native speakers. Contrary to initial expectations, recall performance for congruent words did not significantly exceed recall of control words. As has been repeatedly discussed, it is possible that the unfamiliar presentation format initially hindered processing (Ahlén, Hills, Hanif, Rubino & Barton, 2014) as indicated by longer response latencies in self-paced trials, which may help to explain the lack of a recall benefit. As observed in previous studies, amending encoding conditions from incidental to intentional increased recall scores overall (Noldy, Stelmack & Campbell, 1990; Cohen, 1973; Rüsseler, Hennighausen, Münte & Rösler, 2003). Yet, despite participants' awareness of the recall test, incongruent stimuli remained unaffected and retention did not increase for these items, providing further evidence for the importance of the potential for holistic integration and interpretation of stimulus features (Garner, 1976; Prinzmetal, 1995).

Experiments 7 and 8 also highlighted the beneficial effect of extended exposure during encoding. Longer study time has commonly been associated with better retention (Loftus & Kallman, 1979; Potter, 1976; Potter & Levy, 1969; Tversky & Sherman, 1975), which was confirmed by the results obtained in Experiment 8, where recall increased for all presentation formats, including incongruent items. However, findings obtained in Experiment 2 are indicative that the impact of exposure time is not universal. While positive correlations between exposure duration and recall likelihood were observed for words, pictures and separated stimuli (labelled pictures), no such relationship emerged for integrated stimuli. Thus, while exposure time asserted a significant effect on retention of single dimension and separated stimuli, retention for integrated items was not affected by viewing time. Yet recall rate was equal across presentation formats. This strongly suggests that when stimulus features are designed to yield high retention probability, these features can produce a retention benefit equal to that elicited by exposure time for standard stimuli.

Findings from Chapter 5 highlighted the relationship between encoding conditions and retention test as explained by Eagle and Leiter (1964). Their findings suggested that while using a recall test more accurately assesses intentionally encoded material, retention of incidentally encoded information is more accurately assessed by using a recognition test. As has been previously established, recognition scores were higher than recall scores for all presentation formats, independent of encoding cue (MacDougall, 1904), but the recognition test was clearly more sensitive to incidentally encoded stimuli as well as differences in presentation format. It emerged that integrated stimuli were substantially more memorable than control items regardless of whether they were encoded incidentally or intentionally. Thus it appeared that while integrated stimuli may not have benefitted from superior recall, they did derive a significant recognition advantage. While previous indications had been detected, suggesting that integrated stimuli were not processed in the same way as either single words or single pictures, these results indicated that the novel presentation format did indeed allow these processing differences to result in better retention, if only on a recognition basis. Improved recognition could have been obtained as a result of deeper processing (Craik & Lockheart, 1972) or the unfamiliar format, which would potentially make them stand out against more commonly encountered written or pictorial material (McDaniel & Einstein, 1986; McDaniel, Einstein, DeLosh, May & Brady,1995; Riefer & LaMay, 1998; McDaniel, Einstein &Lackey, 1989; Nicholas & Marchal, 1998). It is also possible that the simple addition of pictorial features resulted in the improved recognition performance as a result of the well-established picture superiority effect (Paivio & Csapo, 1973; Stenberg, Radeborg & Hedman, 1995; Maisto & Queen, 1992). In addition to their recall benefit, pictures have also been found to be more recognisable (De Angeli, Coventry, Johnson & Coutts, 2003; De Angeli, Coventry, Johnson & Renaud, 2005; Jansen, Gavrila, S, Korolev, Ayers & Swanstrom, 2003; Weinshall & Kirkpatrick, 2004), even if they display only abstract patterns (Dhamija & Perrig, 2000). In order to examine the relative impact of verbal and non-verbal information, Experiment 11 tested independent recognition of isolated words or pictures after viewing integrated stimuli during presentation. Results suggested that verbal information was a more reliable identifier to allow accurate recognition than non-verbal information. Although picture recognition has been shown to be more accurate than word recognition (De Angeli et al., 2005; Weinshall & Kirkpatrick, 2004), in these studies it is generally the same picture being recognised rather than a different picture of the same object. On the other hand, although words in the current study change font between encoding and recognition, they still maintain their orthographic integrity and may therefore be easier to rely on for recognition than the pictorial dimension. Clearly, words retain greater recognisability following a substantial change in visual appearance than pictures. While the nature of words is derived from the order in which letters are presented, it is of little importance whether letters are shown in different colours, fonts or sizes and even unfamiliar orientations can be read relatively easily (Ahlén, Hills, Hanif, Rubino & Barton, 2014). Conversely, even a small alteration to a picture stimulus can significantly alter its appearance and interpretation (Lyn & Murphy, 1999). Chapter 6 therefore addressed this issue of stimulus ambiguity, aiming to transfer ambiguity from the non-verbal to the verbal dimension by using homonyms as target items. This approach would help clarify whether the primary use of verbal information as a stimulus identifier occurred as a result of ambiguity in the non-verbal dimension. Findings would also offer further evidence regarding the effectiveness of the alterations made to integrated stimuli in evoking a stronger mental image of the concept in question, leading to improved encoding and retention. When verbal cueing for homonyms was employed, some, but not all, common frequency effects were observed, with high frequency interpretations during encoding yielding better recognition scores than items first encountered with a low frequency bias. Surprisingly, a change in frequency bias between encoding and recognition resulted in higher accuracy than trials in which the frequency bias remained constant. Even more unexpectedly, when non-verbal recognition was tested, effects of frequency bias disappeared entirely. The results suggested that rather than biasing interpretation more strongly towards a single homonym interpretation, integrated presentation resulted in a holistic activation of multiple homonym interpretations, which allowed equiprobable recognition of either interpretation. While this occurred to an extent under conditions of verbal recognition, it was most pronounced when non-verbal bias cues were provided, essentially providing a separated display of verbal and non-verbal information, more similar to encoding conditions.

On the whole the data suggest that holistic conceptual activation can be achieved as a result of integrated stimulus presentation. While presentation of integrated verbal and non-verbal information may not result in better recall as initially anticipated, presentation format had a clear impact on processing and enabled superior item recognition. The findings are compatible with the assumptions of Gestalt psychology, theorising that the meaningful integration of smaller parts can generate a new, holistic object, the entity of which exceeds the mere sum of its individual properties (Wagemans, Elder, Kubovy, Palmer, Peterson, Singh & von der Heydt, 2012; Wagemans, Feldman, Gepshtein, Kimchi, Pomerantz, van der Helm & van Leeuwen, 2012). As shown in this work, either isolated verbal information or the addition of physical features in a design unrelated to stimulus content failed to achieve the same benefits as a combination of meaningfully related verbal and non-verbal material (Garner, 1976).

Applications

As a result of the improved recognisability of integrated stimuli, a number of possible practical applications of findings present themselves. Probably the most obvious area of application will be in the field of advertising, in particular the creation of logos and brand names. If congruency between shape and meaning makes verbal items more recognisable, this may be used by the advertising industry to capture customers' attention and lead them to remember their products substantially better, which could result in widespread popularity in the marketing sector. Logos are an important aspect of brand identity (Sharma & Garikaparthi, 2013) and can help make a product stand out from similar, competing products available on the market (Chan, 1994). Aspects of familiarity and recognisability play a large role in logo effectiveness (Kent & Allen, 1994) and have an important impact on product preference (Perfect & Heatherley, 1997). The features representing an actual object could help make a logo more recognisable and make it seem instantly familiar. Another main function of logo use is to transcend international boundaries and make brands accessible across the world (Kohli & Suri, 2002). For the items used here, international emblems may have to be adapted nationally, to be comprised of words in the local language. Nevertheless, logo design could potentially be preserved independent of verbal content, allowing both aspects of national and international appeal to be successfully combined. At the same time, however, the effect of repeated exposure needs to be taken into consideration (Pieters, Rosbergen & Wedel, 1999), in particular whether the recognition benefit occurs solely as an artefact of bizarreness (McDaniel & Einstein, 1986; Engelkamp, Zimmer & Biegelmann, 1993) or whether even a large number of integrated stimuli can be recognised reliably and over an extended period of time. In fact, firms such as Ikea have already made use of graphically enhanced items when launching their PLAY – LIVE – CREATE campaign and company logos often make use of novel designs to communicate the name or purpose of their business through a non-verbal as well as verbal communication route. Colours, shapes and manipulations similar to the ones used here are commonly observed when looking at existing logos (Landau, Nelson & Keefer, 2015; Cass, 2009; Ajala, 1991). Although the approach is already used in every day life, little research exists to date to verify its effectiveness. The data presented here confirm that physical manipulation of words does indeed increase recognisability and thus has the potential to enhance brand identity. The data support the benefit of seeking an active link between verbal and non-verbal content to aid logo recognition upon subsequent encounters.

Further potential for application of the findings obtained may arise in the production and enhancement of instructional stimuli, in particular in the area of language acquisition, where the use of pictures has repeatedly been shown to be beneficial to learning (Kellogg & Howe, 1971; Ghorbani, 2017; Sun, 2017). Integrated stimuli may be used to make concepts more memorable and easier to access. This, however, would most likely be restricted to more concrete concepts of which a pictorial representation can be generated. Although activation of words in the currently inactive language can be successfully suppressed in proficient bilinguals (Gerard & Cortese, 1984), some activation of non-target language words may still occur (Kaushanskaya & Marian, 2007; Colomé & Miozzo, 2010), leading to significant interference. This would explain why non-native speakers sometimes displayed better performance with incongruent rather than congruent stimuli. It is plausible that congruent features may more readily evoke the verbal label of their primary language, leading to inhibition rather than facilitation of the English label, resulting in the need for additional time to reconvene the verbal information to the shape. Yet, repeated exposure to integrated stimuli may serve to strengthen the link between the concept image and foreign language label, therefore enhancing language acquisition and retention in the long-term.

Limitations

As mentioned in the introduction there are a number of orthographic and semantic factors which may affect the retention of verbal stimuli in addition to the physical manipulation used in the current experiments. Word length, word frequency, orthographic neighbourhood size, age of acquisition, concreteness and imageability all impact the likelihood of recall of verbal material. While it is certainly important to be aware of these factors and consider their impact in memory studies, they are not expected to have a major confounding impact in the current experiments. In each experiment, the same stimuli were used and counterbalanced across conditions to ensure that all participants would see the same words. Consequently, orthographic and semantic factors would affect all conditions equally, with differences between conditions not being attributable to any of these word properties.

Furthermore, the distinction between native and non-native speakers may pose a possible limitation, due to a lack of group homogeneity. The distinction focuses only on first language but neglects the impact of bilingualism, multilingualism and different native languages. Due to the strong language component of the effect under investigation, these distinct categories should be examined in more detail in future investigations. While results have shown that native speakers appear more proficient at using combined verbal and non-verbal cues, the impact of language proficiency in non-native speakers remains unexplored. It is also possible that non-native speakers with languages more similar to English may benefit more than native speakers of dissimilar languages.

An additional limitation, which needs to be considered, lies in the nature of the stimuli themselves. All of the integrated stimuli used in this study were designed as subjective representations of the intended concepts by the author of the current work. It is entirely possible that participants may have disagreed with the best possible representation for the stimuli. In order to address this issue future experiments should aim to undertake a norming process of all integrated stimuli, obtaining independent ratings for both readability of the verbal dimension and recognisability of the non-verbal dimension.

Although the results obtained in the here described experiment predominantly support the automatic processing of non-verbal information, it cannot be conclusively excluded that automatic processing also occurred for the verbal dimension of integrated stimuli. As all participants were studying at university level, they are likely to be skilled readers, who have successfully automated fast and efficient processing of verbal material (Hasher & Zacks, 1979). Consequently, participants may have focused their attention on the most familiar aspects of the stimuli, namely the letters, and attempted to ignore non-verbal features when interpreting the items. Testing both the verbal and non-verbal dimensions separately, for example through the use of picture representations of similar complexity designed from basic geometrical shapes, could shed light on the relative processing automaticity involved for both dimensions.

Future Research Directions

Subsequent research could aim to determine the nature of the difference observed between recall and recognition tests. This should, for example, include recall and recognition accuracy patterns in pictures, which have also been found to be more recognisable than words (Shepard, 1967), and compare them directly to integrated stimuli and words. Weinshall and Kirkpatrick (2004) ran a series of experiments and confirmed that pictures were more readily recognised than words, pseudo words and letter strings conforming to an established pattern. This further suggests that while participants may have focused on the verbal over the non-verbal dimension, integrated stimuli were nevertheless processed in a fashion more similar to non-verbal than verbal material.

Future investigations could also examine the role of personal learning style. Due to the strong visual component in the appearance of integrated stimuli, it is highly likely that visually orientated learners could benefit more easily from the integrated format than those who prefer verbal, auditory or kinetic learning styles. For the use in instructional materials or to enhance language learning, future research should also aim to investigate understanding and memory of a piece of text containing graphically enhanced items as well as individual words.

Future research could additionally examine the long-term retention of integrated stimuli as well as their recognisability over an extended period of time. For use in advertising pleasantness and readability ratings should also be obtained, as these may affect how the stimulus is perceived by an observer (Whissell & McCall, 1997). While all encoded material follows a similar pattern, with initial rapid decline in recall accuracy before forgetting slows for the remaining retained items (Ebbinghaus, 1966), it has been observed that pictures are more easily retained over a longer period than words (Erdelyi & Becker, 1974). In addition, incremental memory with repeated recall has been observed with pictures but not words (Erdelyi & Becker, 1974), although repeated retrieval can also aid memory performance for other material (Karpicke & Roediger, 2007). In addition, recall is better for meaningful verbal material (Briggs & Reed, 1943; Hovland, 1951) and increases dramatically for songs or verse with words being remembered accurately even after years (Rubin, 1977), with similar findings having been obtained for procedural knowledge following a two-year period (Allen & Reber, 1980). Finally, Mitchell (2006) reported that participants performed above chance in a fragment completion task relating to images they had viewed 17 years prior for between 1-3 seconds. They performed significantly better than non-participants even when reporting that they could not consciously recall having participated in the initial study. Integrated stimuli may also have an added long-term recall advantage due to their unusual design. Research has suggested that bizarre material is recalled better over a longer period of time, particularly when presented alongside non-bizarre items (Iaccino, Dvorak & Coler, 1989), possibly as a result of cognitive elaboration (Andreoff & Yarmey, 1976).

Conclusion

In sum, the present work examined how holistic, conceptual processing could be achieved by meaningfully integrating verbal and non-verbal information into a single visual object, which would allow simultaneous, complementary encoding of both dimensions. The main interest of the current work was in the exploration of encoding and retention mechanisms associated with holistic processing. While both pictures and words have been investigated in isolation, less research exists to explore the complementary potential of both presentation formats. Even in instances where combined presentation is used, such as the Stroop effect (Stroop, 1935) the primary focus has been on interference rather than facilitation of processing.

Overall results showed that holistic integration could be achieved successfully and visual integration of verbal and non-verbal information led to processing of both dimensions as a single object rather than as separate dimensions. While there may not be a direct recall benefit of integrated verbal and non-verbal information, combining pictures and words into a single visual object significantly increases stimulus recognisability regardless of encoding intention. In addition, holistic activation was achieved for verbally ambiguous stimuli.

Findings indicate that integrated presentation of verbal and non-verbal information is encoded through a mostly incidental route, which is most accurately tested by using a recognition test. In addition, data show that although participants appear to rely mostly on the verbal dimension for positive identification of targets, non-verbal information is encoded successfully and significantly impacts encoding and retrieval processes. Results suggest that while integrated presentation does not aid free recall, it is highly effective in improving stimulus recognisability.

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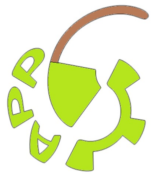
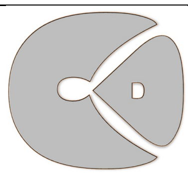
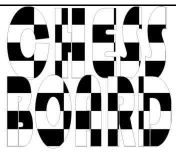
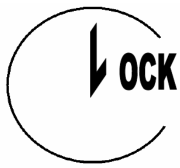
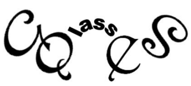
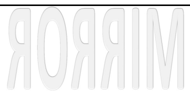
APPENDIX

The appendix contains itemised data for integrated congruent stimuli used in each chapter. Obtained measures are shown for word length, word frequency, recall/recognition scores and reaction/recognition times where applicable. Correlational analysis was also carried out to explore any possible relationships between these variables.

stimulus	word length	word frequency	recall percentage	reaction times (SD)
	5	26.51	10	7956.43 (7765.78)
	6	5.32	76	1923.67 (1554.01)
	10	1.47	30	5179.00 (5354.43)
	5	3.35	30	4644.06 (4771.99)
	6	7.87	26	2836.45 (1845.41)
	5	3.27	10	2966.16 (5899.60)
	6	3.83	56	2268.73 (1735.90)
	2	10.67	6	7825.18 (11309.24)
	6	25.59	50	3208.10 (4332.57)

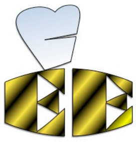
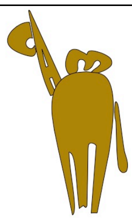
	8	2.29	16	7637.35 (7193.00)
	10	0.25	30	3272.65 (2192.66)
	9	20.91	20	3115.39 (3917.36)
	5	28.46	26	3172.53 (4622.93)
	3	121.4	16	5872.76 (6360.29)
	7	4.95	20	9717.88 (9872.82)
	7	23.72	16	8044.06 (8461.17)
	7	5.78	26	2716.86 (2310.22)
	9	0.12	20	4687.67 (3541.67)
	9	0.27	20	3222.92 (2979.71)

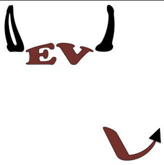
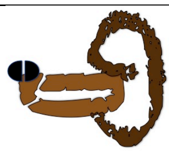
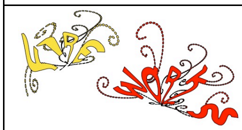
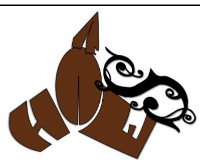
	8	3.87	16	2527.65 (1902.76)
	6	37.97	54	2538.57 (1978.86)
	8	3.35	10	4039.27 (5662.15)
	6	5.91	6	2615.86 (2595.61)
	6	84.97	26	2890.76 (3259.63)

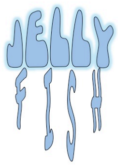
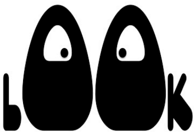
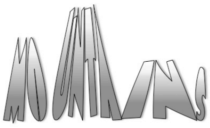
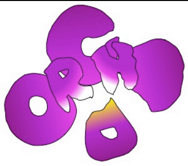
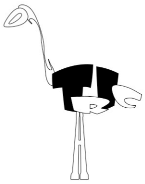
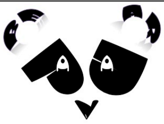
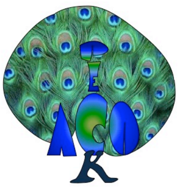
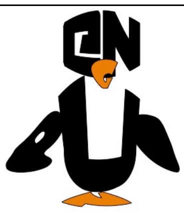
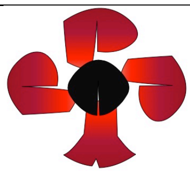
CORRELATIONS		word frequency	recall percentage	reaction times
word length	r-value	-.459*	.041	-.167
	p-value	.024	.849	.437
word frequency	r-value		-.027	.057
	p-value		.901	.790
recall percentage	r-value			-.460*
	p-value			.024

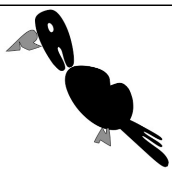
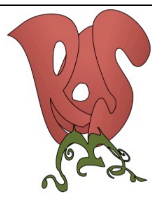
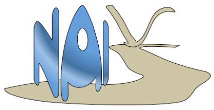
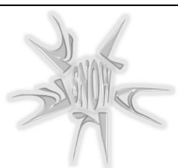
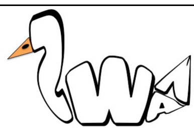
n=24

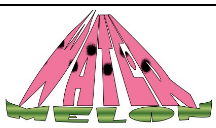
CHAPTER 3 – Due to simplistic nature and repetitive presentation of the stimuli as well as the absence of a recall/recognition task, no appendix data is available for these items.

stimulus	word length	word frequency	recall percentage	reaction times (SD)
	8	3.82	5.00	2565.53 (1730.53)
	6	2.91	16.67	3003.33 (2264.46)
	3	5.22	15.00	4344.87 (5045.77)
	4	32.26	15.00	3529.00 (2390.49)
	5	19.74	6.67	2458.73 (1176.88)
	5	3.66	30.00	3508.67 (3108.89)
	3	39.1	43.33	1839.00 (1092.76)
	9	0.97	8.33	2801.33 (1454.79)
	10	0.11	10.00	4523.20 (3041.83)

	13	1.95	1.67	3954.20 (1962.06)
	6	5.85	15.00	4692.07 (3457.74)
	5	16.69	23.33	2847.20 (2353.88)
	3	79.79	13.33	3412.87 (3287.14)
	5	48.48	25.00	3837.93 (2878.65)
	9	3.57	36.67	3007.93 (1022.72)
	4	15.14	35.00	3982.87 (4380.80)
	5	13.4	11.67	2828.33 (1708.20)
	5	76.09	3.33	3865.00 (2815.41)

	9	0.84	35.00	2334.47 (1275.12)
	8	0.66	30.00	2176.40 (2200.93)
	4	528.64	21.67	3477.67 (4273.08)
	9	28.09	13.33	3379.93 (2601.69)
	6	2.17	1.67	4512.20 (3605.42)
	7	1.31	18.33	4104.13 (3449.09)
	9	1.79	6.67	3503.13 (3958.52)
	7	4.84	33.33	3416.80 (2203.05)
	7	4.8	33.33	2045.20 (1351.34)
	5	2.7	1.67	3402.87 (1885.30)

	6	0.23	5.00	4286.00 (2894.55)
	5	1.96	0.00	4021.53 (3083.55)
	8	1.5	8.33	3650.93 (2871.36)
	4	68.69	6.67	4030.47 (3895.46)
	4	108.03	10.00	3606.20 (3499.99)
	5	1.47	20.00	1721.53 (1133.60)
	5	2.97	10.00	3453.40 (2009.29)
	9	0.32	15.00	2928.13 (2233.76)
	9	1.17	10.00	5028.53 (4544.69)
	4	9.97	13.33	1925.00 (845.73)
	7	1.29	23.33	2211.80 (1146.49)

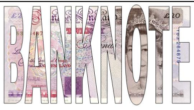
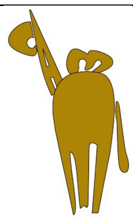
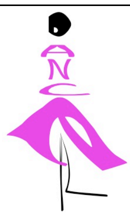
	6	68.12	13.33	3159.13 (2069.55)
	12	2.75	28.33	2582.27 (1990.42)
	8	7.84	36.67	2848.87 (2349.26)
	4	4.83	20.00	4362.60 (10283.70)
	7	3.92	18.33	4807.20 (3287.59)
	10	0.19	40.00	2420.80 (1082.06)

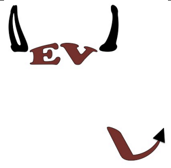
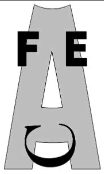
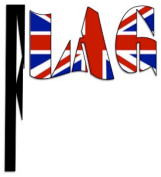
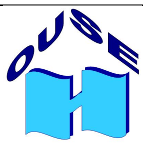
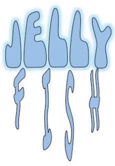
CORRELATIONS		word frequency	recall percentage	reaction times
word length	r-value	-.294	.055	-.057
	p-value	.050	.721	.712
word frequency	r-value		.008	.042
	p-value		.958	.786
recall percentage	r-value			-.442**
	p-value			.002

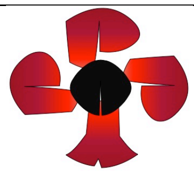
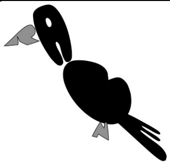
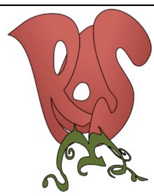
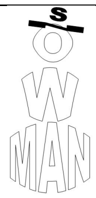
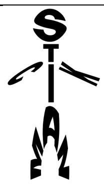
n=45

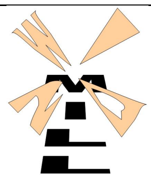
CHAPTER 5 – Experiments 9-11

stimulus	word	word	recall	recognition	reaction

	length	frequency	percentage	percentage	times (SD)
	8	0.16	35	90	1268.4 (697.98)
	4	32.26	20	80	1491.85 (701.57)
	5	19.74	30	60	1458.65 (796.66)
	3	252.46	20	65	1172.25 (517.31)
	6	69.84	20	55	1135.2 (277.85)
	5	3.66	25	80	1777.75 (1380.58)
	3	39.1	35	70	1405.85 (887.25)
	9	0.97	20	75	1591.8 (1187.64)
	9	20.91	35	80	1397.5 (649.96)
	8	24.46	20	65	2409.65 (4118.27)
	6	5.85	25	70	1381.1 (671.22)

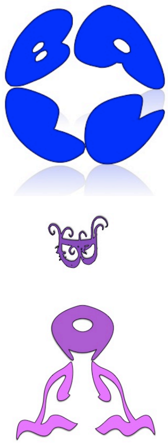
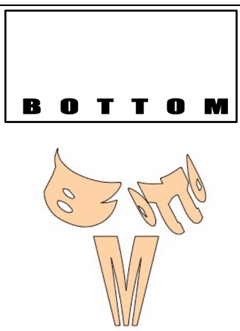
	5	16.69	30	85	1640.5 (1302.09)
	4	332.7	10	75	1771.95 (1223.30)
	4	15.14	30	80	1338.55 (687.10)
	5	1.77	20	70	1471.8 (988.84)
	8	2.59	15	80	1415.85 (615.95)
	4	45.08	15	85	1226.15 (585.46)
	5	500.01	45	75	1398.4 (764.41)
	9	0.84	30	70	1851.45 (1433.04)
	8	0.66	35	80	1086.95 (393.43)
	9	0.27	10	85	1793.45 (2438.87)

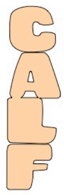
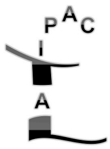
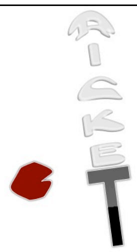
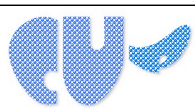
	5	2.7	5	70	3009.45 (7113.76)
	6	0.23	10	85	1626 (1435.16)
	5	1.96	0	75	1687.45 (2071.01)
	4	108.03	20	75	1302.7 (554.38)
	7	0.77	15	85	1360.05 (686.64)
	8	0.03	25	60	1318.05 (885.89)
Stretched	9	19.79	25	80	1361.2 (832.22)
	4	9.97	30	75	1215.75 (463.54)
	8	7.93	20	80	1211.05 (434.37)
	4	4.83	10	80	1390.3 (730.96)

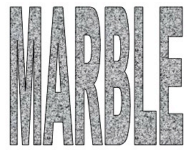
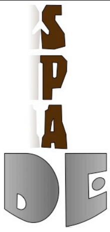
	8	1.86	25	70	1318.8 (596.84)

CORRELATIONS		word frequency	recall percentage	recognition percentage	recognition times
word length	r-value	-.357*	.109	.113	.051
	p-value	.045	.552	.537	.780
word frequency	r-value		.209	-.142	-.081
	p-value		.251	.437	.659
recall percentage	r-value			-.057	-.400*
	p-value			.757	.023
recognition percentage	r-value				-.098
	p-value				.594

n=32

stimulus	word length	word frequency	word recognition percentage	picture recognition percentage	reaction times (SD)
	4	75.36	57.14	59.52	5026.63 (5925.57)
	3	78.09	85.71	80.95	2195.56 (1809.87)
	4	11.14	90.48	69.05	2769.40 (2299.77)
	6	74.61	66.67	66.67	3378.07 (3953.24)
	3	87.3	71.43	54.76	3798.10 (3529.40)

					
 	4	6.49	90.48	76.19	2496.04 (1810.13)
 	7	137.67	47.62	35.71	7501.35 (62.56.25)
 	6	320.06	80.95	69.05	3687.68 (3533.75)
 	7	33.05	52.38	57.14	5001.38 (3742.91)
	3	121.4	71.43	69.05	3678.29 (5110.47)

					
 	4	6.52	38.10	59.52	3980.00 (4042.81)
 	6	13.13	90.48	88.10	2828.47 (3775.61)
 	5	3.03	80.95	76.19	3346.34 (3400.23)

CORRELATIONS		word frequency	recognition percentage - words	recognition percentage - pictures	recognition times
word length	r-value	.194	-.262	-.275	.514
	p-value	.525	.388	.364	.072
word frequency	r-value		-.023	-.235	.261
	p-value		.941	.440	.389
recognition percentage - words	r-value			.779**	-.757**
	p-value			.002	.003
recognition percentage - pictures	r-value				-.889**
	p-value				.000

n=13