Using a Fast Mapping Approach to Investigate Children's Learning about Artefacts

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Abstract

Over nine experiments I investigated young children's ability to learn the names, actions and functions associated with artefacts. Experiment 1 examined whether children, performing a referent selection task, attach a novel action to a novel referent (i.e., applied mutual exclusivity). Children chose the novel artefact significantly more often than chance. Experiments 2 and 3 used tests of comprehension and extension to investigate whether children fast map novel artefact names and actions. I used a strict definition of fast mapping: incidental learning, minimal exposure, and long term retention. Accuracy was above chance, with no significant differences between action and naming. Experiments 4, 5 and 6 created and refined a methodology designed to study children's ability to fast map an artefact's name, action *and function*. Following brief incidental exposure to an artefact's use (i.e., making a music box play), 3- and 5-years-olds were equally likely to fast map a novel name, action and function. In a more challenging task, with just one demonstration of the novel artefact information, 3-year-olds found action easiest to remember in a test of *comprehension*. Experiment 7 investigated 4-year olds' *production* of names and actions after a brief exposure. Actions were produced substantially better than names. Experiment 8 used referent selection tasks to further test 3-year-olds' mutually exclusive behaviour. Once again, performance with name, action and function did not differ. This suggests children believe that artefacts are associated with a specific name, action and function, and that these are *characteristic* features of an artefact category. Experiment 9 investigated which of these features we regard as *defining* category membership: 3-year-olds tend to categorise by shape, whereas older children (and adults) prefer function. Overall, my data suggest that young children are excellent learners of artefact information, although the way humans categorise artefacts may change during later development.

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Chapter One

General Introduction

1.1 Overview

As adults living in a western society we come into contact with hundreds of artefacts every day. An artefact is defined as any object made by humans, specifically with a view to its subsequent use. We rely on a plethora of different artefacts of varying complexity: alarm clocks, mobile phones, cutlery, pens, laptops etc. These artefacts reflect both our understanding for the world in which we live, and the capacities of our own bodies (Johnson-Frey, 2004). For children born into a western society, it is clear that there is much to learn about their artefact rich world. The questions are what information do children need to learn in order to use an artefact, how do they learn it, and how does this knowledge develop?

In order to use an artefact in an artefact rich society, I suggest, children need to know three principal things. These are the action, the function, and the name associated with that artefact.

In all cases, actions are the product of sensorimotor representation (Boncoddo, Dixon & Kelly, 2010; Rakison & Woodward, 2008). Of course actions need not utilize artefacts – for example when waving a hand or dancing. Using an artefact usually entails the combination of a *specific* artefact with a *specific* action. The artefact must be held with the correct grip and orientation, and then manipulated in the correct way (Johnson-Frey, 2003, 2004). In contrast, the function of an artefact is the effect it has when used. That is, a specific action-artefact combination brings about a specific change to the environment. This is often a change to a specific substance or object, which is referred to here as the artefact's 'substrate'. For example, when a hammer (the artefact) is used, it is held by its handle with the head on top (grip and orientation); the arm and wrist are moved in such a way (the artefact's action) as to bring the head of the hammer into contact with the nail (the artefact's substrate). This contact drives the nail into the surface on which it is held (the artefact's function).

Actions involving artefacts are inextricably linked to those artefacts' functions: artefact, action and function are bound together. At the most superficial level, there is an associative contingency between artefact-action-function, as an artefact's function is usually achieved when the action and artefact co-occur (e.g., a nail is driven when the appropriate limb-movement is made with a hammer held in the correct way). At a deeper level, there is a causal narrative, which describes how specific properties of the artefact interact with specific properties of the action made with it and thereby achieve its function. This narrative can be described in terms of everyday language (e.g., the nail is hit hard with the heavy hammer) or with more scientific rigor (e.g., in terms of forces or the atomic structure of materials involved). Children must start by learning some information associated with an artefact (its action and function). Finally, children also need to learn the artefact's name. That is the phonological representation that labels the artefact. Knowing an artefact's name is essential if children are to fully appreciate the more subtle aspects of some artefacts' social function (e.g., money or art), or to learn more about how the artefact works (i.e., the more complex causal narrative).

My thesis focuses on young children's (3- to 5-year-olds) ability to learn these three pieces of essential information about an artefact. In particular, I develop a procedure to investigate what children learn about artefacts following a brief exposure in a 'real world' context. I investigate children's comprehension and production of artefact information following this brief exposure. I also investigate how this information is utilised by children when reasoning about artefacts. My research question, ‘How do young children acquire and apply their knowledge of artefact use?” is quite novel, although it relates to research described in a number of literatures.

Much of the previous research – on referent selection and fast mapping – has focused on artefact naming. I have extended this historically ‘word learning’ literature to investigate the acquisition of knowledge about the actions and functions associated with artefacts. The referent selection literature recognises that the presentation of novel name causes children to attend to novel artefacts (Horst & Samuelson, 2008). Word learning principles (e.g., mutual exclusivity and whole object bias – Markman, 1987; Golinkoff, Mervis & Hirsch-Pasek, 1994; Markman, Wasow & Hansen, 2003) can be used to explain why children attend to novel artefacts when presented with a novel name. The Fast Mapping literature indicates how children *learn* artefact names (e.g., Markson & Bloom, 1997; Holland, Simpson & Riggs, 2015).

A larger literature has investigated the development of imitative behaviour. This literature offers a different perspective on artefact action and function learning (e.g., Simpson & Riggs, 2011a; Simpson, Cooper, Gillmeister & Riggs, 2013). In contrast, a small literature has begun to examine how children respond to novel artefact actions and artefact functions (Childers & Tomasello, 2002, 2003; Hahn & Gershkoff-Stowe, 2010; Casler and Kelemen, 2005, 2007). The ‘extension’ literature examines which artefact features are deemed characteristic of the category to which an artefact belongs, and thus extendable to other members of that category (e.g., Deák, Ray & Pick, 2013; Childers & Tomasello, 2003; Waxman & Booth, 2000). Finally the ‘categorisation’ literature aims to establish which features are viewed as *defining* category membership, rather than merely being associated with it (e.g., Smith, Jones & Landau, 1996; Kemler Nelson, 1999).

It is difficult to integrate research from these different literatures, and so develop a coherent narrative in my thesis. To help the reader orient themselves with respect to these literatures, I begin by defining the key terms used in them. After that, the next section begins by reviewing research from the referent selection and fast mapping literatures, as it applies to *word* learning. Fast mapping of other kinds of information is then considered. Next, a very brief review of imitation research is included. I discuss the similarities and differences between an imitation approach to minimal exposure learning about artefacts' action and function, and a fast mapping approach to learning about artefacts action and function. Following that, I introduce categorisation literature, with particular regard to the observation of a shape bias in young children's artefact categories (i.e., they tend to categorise artefacts by their shape). Briefly I describe two accounts to explain this bias: the Attentional Learning Account and the Shape-as-Cue account. A key questions is, once children have learned novel information about an artefact category, how does this information contribute to their understanding and definition of that category or future categories?

I will return to the aforementioned literature in the relevant empirical categories. Nine experiments are grouped into three chapters. Chapter Two describes three experiments investigating whether children can engage in referent selection and then fast map both artefact names and artefact actions to pass tests of comprehension and extension. In Chapter Three, I detail a methodology designed to examine young children's ability to fast map an artefact's name, action and function. Four experiments refine this methodology to investigate which information children find easiest to learn. Chapter Four examines children's ability to select and categorise of novel artefacts using name, action, function and shape information.

1.2 Key Terms

1.2.1 Fast Mapping

The term 'fast mapping' labels an experimental learning process first developed by Carey and Bartlett (1978). This methodology was designed to approximate a child's everyday *word* learning experience. Unfortunately, the term fast mapping is not consistently applied. Researchers tend to interpret the term in slightly different ways. For the purposes of this thesis, I will use three key experimental features, taken from Carey and Bartlett's original study, as definitive criteria. Firstly, as children are not explicitly taught every new word they learn in the real world, the fast mapping procedure should involve no direct teaching. Secondly, using their study as a guide, a fast mapping methodology involves only a single learning session with limited exposure to the new word. Finally, to demonstrate learning, retention should be tested for after a significant delay (i.e., more than just a few minutes). These criteria are pertinent as they allow us to study learning using a controlled, experimental procedure whilst simulating a natural learning environment.

In later work, the other key study in the literature (Markson & Bloom, 1997) defines fast mapping in a similar way. Markson and Bloom describe fast mapping as a learning process through which children observe few incidental exposures and demonstrate long-term retention. Thereafter, many researchers define fast mapping in a much less stringent way. That is, fast mapping is merely the process of selecting the referent for a novel word (Horst & Samuelson, 2008).

1.2.2 Incidental Learning

Incidental learning describes an important methodological feature of fast mapping. With incidental learning, novel information is presented to the participant but not explicitly (i.e., so not 'Here is some important novel information – remember it!'). The focus of fast mapping task is not overtly about learning this new information at all. In some previous studies involving incidental learning, the main focus of the child's time with the experimenter is to play a game (e.g., "…children were told it was a game…" Markson & Bloom, 1997; p 813). Furthermore, once the children have been exposed to the novel information, they should not be encouraged to learn or remember the novel information.

1.2.3 Minimal Exposure

Minimal exposure is another key feature of fast mapping. It requires experimenters to limit the number of presentations of the novel information to the child. In a typical fast mapping study children are only told the novel information between one and three times (e.g., Markson & Bloom, 1997; Vlach & Sandhofer 2012; Deák & Toney, 2013; Holland, Simpson & Riggs, 2015). Moreover, the exposure of the novel information, within the experimenter-child interaction, is brief. For example, in the five to 10 minutes spent with the experimenter, the novel information may be presented in one to three sentences – each of which lasts only a few seconds.

1.2.4 Retention

Retention describes the ability to store information long term: it is the third and last of the features I use to define the fast mapping methodology. In a traditional fast mapping task, a test of retention is required to demonstrate that *learning* has taken place. In both

Carey and Bartlett's original study (1978) and Markson and Bloom (1997), children were tested one week after their initial exposure to a novel word. For example, in Markson and Bloom's investigation of novel artefact name learning, children were asked to select a target artefact, from a choice of unfamiliar items, one week after initial exposure of the novel label. More recently, Holland, Simpson & Riggs (2015) have stressed the importance for assessing retention after a long-term delay to truly understand learning processes. Although some developmental investigations test for retention after a much shorter delay (e.g. 5 minutes, Horst & Samuelson, 2008), I employ the more exacting standard used in the original fast mapping studies: a delay of about a week.

1.2.5 Referent Selection

The term 'referent selection' has been used to describe the process that allows us to use our understanding of familiar stimuli, to correctly select a novel target when hearing an unfamiliar word (Mather & Plunkett, 2012; Horst & Samuelson, 2008; Halberda, 2006; Diesendruck & Markson, 2001). Using Carey & Bartlett's (1978) initial fast mapping study as an example: Children were shown a red and an olive colour tray, and asked to retrieve the 'chromium' tray. As children already had an understanding of the colour red, they were able to identify that the experimenter was referring to the other tray, and that therefore this was the referent for the novel word 'chromium'. In Carey & Bartlett's study children successfully selected and retrieved this tray.

1.2.6 Mutual Exclusivity

Markman (1987) originally proposed the mutual exclusivity principle in relation to word learning: it is a process that may occur during referent selection. It describes an understanding that individual categories in the world cannot receive more than one label. For example, if something is labelled ‘chair’ it cannot be given a second, different name. This principle means that a novel name cannot be applied to anything that already has a name. It is suggested that this principle allows children to successfully complete referent selection tasks (Markman, Wasow & Hansen, 2003). Although Markman’s initial theory dictates that children will reject giving objects more than one name, thus look for an unfamiliar exemplar, alternative theories exist suggesting children actually demonstrate a simpler bias towards novelty (Mervis, Golinkoff & Hirsch-Pasek, 1994).

Despite mutual exclusivity’s initial affiliation with language acquisition researchers, whose theories propose domain-specific mechanisms (Markman & Wachtel, 1988; Merriman & Bowman, 1989), some current researchers believe that mutual exclusivity simply describes children’s more domain-general assumption that categories either are distinct (i.e., Riggs, Mather, Hyde & Simpson, 2015) or are at least *understood* to be distinct by interlocutors through shared understanding (Childers & Tomasello, 2003). It is thus believed that this behaviour will be demonstrated beyond simply names, for example children demonstrate mutually exclusive behaviour when selecting the referent for an artefact action (Riggs, Mather, Hyde & Simpson, 2015).

1.2.7 Extension

Extension is key to learning new words (Bloom, 2000). We would be unable to learn new words so quickly if we didn’t understand that once we had learned a novel word (e.g., chair), this label can then be extended to all other members of that category (chairs). For example, after children have learned a novel name for a novel artefact, in extension tasks they are then asked to find further examples of the same artefact category (Waxman &

Booth, 2000; Jaswal & Markman, 2003; Jones, Smith & Landau, 2001). If children successfully attach their novel name to similar items (usually the same shape, but differing in other features such as size, colour and/or texture – see section 1.2.10), it demonstrates that they understand that the word they have learned applies to all other items that belong to the same category as the initial item (Markson & Bloom 1997; Childers & Tomasello, 2003; Deák & Toney, 2013).

1.2.8 Categorisation

Categories refer to groups of items or instances that are seen as intrinsically similar in nature. Categorisation is the behaviour whereby we identify these group similarities within a variety of things, and thus form such categories (Sloutsky, 2003). When examining our vocabularies and our understanding of artefacts it is clear that we are able to group similar artefacts into categories, and that this is a necessary skill for vocabulary acquisition (Smith & Samuelson, 2006). Two laboratory tasks are commonly used to investigate categorisation. Previously mentioned extension tasks examine which artefact features children recognise as characteristic of an artefact category, and so allow items to be grouped on the basis of these features (Childers & Tomasello, 2003; Casler & Kelemen, 2005; Jones & Smith, 2002). Categorisation tasks, often in a forced-choice procedure, investigate which of these features is deemed definitive of the category (Landau, Smith & Jones, 1998; Kemler Nelson et al., 1995; Booth & Waxman, 2002).

1.2.9 The Shape Bias

The shape bias describes a preference for shape over other features when defining an artefact's category (Landau, Smith & Jones, 1988, Smith, Jones & Landau, 1996). Landau, Smith and Jones (1988) propose that early language acquisition teaches children to partition the world according to shape. They suggest that young word learners attend to shape as the critical factor when making decisions on how to extend and define novel nouns. Smith and colleagues propose the Attentional Learning Account to explain the shape bias (see section 1.5.3 – Smith, Jones, Landau, Gershkoff-Stowe & Samuelson, 2002; Colunga & Smith, 2008). They suggest that as children's vocabulary increases, they begin to attend (without deliberative thought), to the perceptual similarities between objects they have previously experienced being labelled with the same name. Once this link has been established it allows children to learn other object names more rapidly, via an automatic attention to shape mechanism (Smith Jones, Landau, Gershkoff-Stowe & Samuelson, 2002; Colunga & Smith, 2008).

1.2.10 Essentialism

Humans understand the world to be made up of natural categories (e.g., dogs, apples, lakes). Natural categories refer to a natural grouping reflecting the structure of the natural world and, arguably, not a human interpretation of it. Essentialism is a philosophical term suggesting that we have a naïve intuition that certain natural categories, have causally, deep hidden properties, known as essences. (Locke, 1960 – cited in Bloom, 2000; Kelemen & Carey, 2007). These essences, while we do not always know what they are, ultimately define our categories: thus essentialism is one way to explain human categorisation.

Kelemen and Carey (2007) summarise theories suggesting that adults' reason about artefacts in terms of their intended functions. Intended function performs the same role in creating artefact categories, as essences perform in considering natural kinds (Kelemen & Carey, 2007). Functions are not obvious when perceiving an artefact (particularly when, as is usually the case, it is not being used); nevertheless artefacts can usually be categorised by their function. Bloom (2000) proposes that children have a similar essentialist understanding of artefacts. Children intuitively know that some deeper characteristic (essence) binds members of an artefact category together; we do not need to know what these deeper properties are, simply that they exist. He proposes that children possess a 'general instinct' that artefact labels reflect what the artefacts really are (i.e., their essence), not merely how they appear to be (Bloom, 2000).

1.2.11 The Design Stance

The design stance is another term from philosophy. It describes a conceptual understanding that all artefacts were created, and thus thoughtfully designed, by their maker (Dennett, 1987, 1990). In psychology, it has been proposed that, as adults, we understand that a designer has created an artefact in order to fulfil a certain purpose or function (Bloom, 1996; Kelemen, 2004). As such, when designed, artefacts' physical properties will be specifically arranged to achieve this goal. It is this understanding that allows us as adults to infer an artefact's function from its shape (Kelemen & Carey, 2007; Michaels, 2003; Kemler Nelson, Herron & Morris, 2002). For example, scissors imply cutting due to their sharp edges. Researchers are interested as to whether children demonstrate such an understanding and how and when it develops. Some suggest that when children are given detailed information regarding an artefact, and its intended function, they will use this to aid category formation (Kemler Nelson, Russell, Duke & Jones, 2000). This theory is complemented by a Shape-as-Cue Account of the shape bias, which suggests children attend to artefact shape as a cue for its intended function (see section 1.5.4; Bloom, 2000).

1.3 How We Learn About Artefacts: Word Learning Research

1.3.1 Word Learning Through Fast Mapping

As anthropologists have shown (Gaskins & Paradise, 2010), and as we know through our own life experience, children are not explicitly taught everything they learn. A good example of this is vocabulary acquisition; in a lifetime the average native English speaker will acquire tens of thousands of words (60,000 to 100,000; Bloom, 2001), and it is estimated that by the age of six years children are proficient users of 6,000 to 14,000 of them (Carey, 1978). However knowledge of these, on average, 10,000 words, does not depend upon an adult sitting down and overtly teaching a child each one. Instead, children have learning processes through which they can amass, over time, large amounts of information without such overt support. Exactly how children learn these words is a matter for debate. One school of thought suggests that word learning relies on domain-specific mechanisms (Markman 1989; Waxman & Booth 2000). Others go further to suggest that some domain-specific word-learning mechanisms are automatic (Samuelson & Smith, 1998). One such hypothesised domain-specific and automatic learning process is called 'fast mapping' (Heibeck & Markman, 1987; Waxman & Booth, 2000).

The fast mapping methodology was designed to approximate a child's everyday word learning experience. In Carey and Bartlett's (1978) original, study children were given single exposure to a novel word as part of classroom interaction. In a referent selection task (section 1.2.5), the nursery teacher, pointing to two trays, and asked a child to "Bring me the chromium one. Not the red one, the chromium one." This task made use of children's ability to use mutual exclusivity (section 1.2.6): to recognise that the novel word must label the novel colour. In this instance the children heard the novel word 'chromium' spoken 'as if' they already understood what the word meant. Is this not how most infants encounter the vast majority of the vocabulary they acquire? Through hearing the word spoken 'conversationally' by a more skilled language users, and inferring its meaning through contextual cues (Bloom, 2000).

Carey and Bartlett tested the children's comprehension of new words after 10 minutes, and after a delay of one-week. Children were asked to identify the colour chromium from an array of coloured stimuli. Successful *retention* thus demonstrated the ability to maintain, recall and accurately re-use information long after its initial introduction. It is clear that to demonstrate legitimate learning children must be tested after a substantial delay period. Without a delayed test for retention, it is unclear whether participants have established a stable name-category representation (i.e., 'chromium' means olive colour), or whether a 'correct response' is merely the repetition of something they have just done (i.e., selected the olive colour – Horst & Samuelson, 2008).

Perhaps surprisingly, given how influential this study was for subsequent research, only eight of the 19 participants (47%) correctly identified the "chromium" coloured item during the comprehension task (chance performance = 11%). This wasn't significantly different from a control group, who did not receive any preliminary training, and were simply shown an array of coloured items and asked the same comprehension question. Six (30%) managed to correctly select the target colour with no previous exposure. Nevertheless, this work was significant in driving further investigations of fast mapping. It provided a way for researchers to use a naturalistic, laboratory-based task to investigate what sort of words can be fast mapped. Using the same methodology, Heibeck and Markman (1987) investigated fast mapping of novel shape, colour and texture words, finding shape mappings the most reliably fast mapped after a ten-minute delay. More recently Holland, Simpson and Riggs

(2015), examined the fast mapping of artefact label, shape, colour and texture words in both the short term (after 5 minutes) and long term (after 1 week). They found that, while all types of word were retained in the short term, only artefact labels were retained long term, after a one-week delay.

1.3.2 Word Learning Principles Applied in Fast Mapping

There are many processes at work when children learn a new word through engagement in a fast mapping task. Initially, it is important children are able to recognise which attribute the newly heard word should be applied to. For children to infer a novel word meaning in a single session without explicit labelling, they must be making *assumptions* about what the word means. In this environment, they haven't encountered the word in a sufficient range of contexts, as such, they are unable to 'triangulate' on the meaning. They must rely on their knowledge of word learning principles to guide the meaning that they infer.

Markman (1987, 1989, 1990) suggested two principles are used by children when fast mapping new words: whole object labelling and mutual exclusivity. Markman and colleagues (Heibeck & Markman, 1987; Baldwin & Markman, 1989), obtained data through a series of experiments, consistent with two principles (or biases) that guide children's word learning. First, when children are presented with a novel label for an unfamiliar object, they assume that the novel word labels the object as a whole – not one of its parts or characteristics. Markman (1990) used the example of a dog, suggesting that children understand that the word refers to the creature as a whole, and not simply identifying its tail or the colour brown or the texture furry. This principle is supported by her aforementioned fast mapping data, which suggests children are more proficient at fast mapping novel shape words than novel colour or texture words (Heibeck & Markman, 1987).

Markman's second word learning principle is that children attach new labels using mutual exclusivity. Markman suggests children understand "…that each object will have one and only one label." (Markman, 1990; p. 66); a chair cannot be named a chair and also a pencil (1987, 1989, 1990). Thus, we cannot attach two different labels to a single object category; there is a one-to-one correspondence between categories and words. Naturally, as adults and proficient language users, we understand that within this broad constraint there are exceptions and different levels of categorisation. These can lead one object to have multiple labels (e.g., a spoon can also be labeled 'cutlery' and 'teaspoon'). It is this understanding of mutual exclusivity that allows children to successfully complete the referent selection component of many fast mapping tasks. Upon seeing both a familiar and unfamiliar object, and hearing a novel label, children assume the novel label must attach to the unfamiliar object as they already have a label for the familiar one.

So what is the difference between fast mapping of a novel word and merely completing a referent selection task? Simply, the difference lies in retention. A referent selection task can be described as an 'on-line' task which requires no construction of a name-category representation, and thus no retention (Horst & Samuelson, 2008). Contrarily, fast mapping is a learning process, and one cannot claim learning without a demonstration that information has been accurately retained long term. Referring back to Carey and Bartlett's methodology, it is apparent that to complete the initial referent selection task it only requires the participant to make a quick, selection, without having to consider anything further or processing at a deeper level. The children know that one tray is red, so they were able to complete the task by simply excluding that tray and selecting whatever was left (the olive tray). In fact, referent selection did not require them to actually pay attention to the novel tray or its specific colour. Simply to pass the task, they can select chromium by exclusion - it's not the red one.

To complete a fast mapping task children are required to retain and recall the novel name-category link and use it at a later date. Understanding this, fast mapping could be defined as the process by which we can use an on-line task to facilitate, and so pass, the off-line task of comprehension one week later.

1.3.3 Is Fast Mapping Domain Specific?

Some language researchers believe that fast mapping is a domain-specific learning process unique to language acquisition (e.g. Waxman & Booth, 2000). If this were the case, you would expect the fast mapping of words to be a robust phenomenon. However, despite initial successes (Carey & Bartlett, 1987; Heibeck & Markman, 1987; Markson & Bloom, 1997), more recent fast mapping methodologies and data are far from consistent. These findings are reported as fast mapping by the authors, however do not always meet my definitive criteria (incidental learning, minimal exposure and long-term retention). Positive findings include Gershkoff-Stowe and Hahn's (2007) observation of fast mappings in 16 to 18 month-olds, tested over a number of weeks. Spiegel and Halberda (2011) have found novel label retention, from single exposure, in 2-year-olds. While Jaswal and Markman (2003) found accurate comprehension of novel names in 3-year-olds after a two-day delay; and Waxman and Booth (2000) demonstrated 4-year-olds successfully retain words after a week's delay.

Negative findings are also well represented in the literature. For example, Horst and Samuelson (2008) found poor retention in 24 month-olds, after only a five-minute delay.

Furthermore, Vlach and Sandhofer (2012), followed Markson and Bloom's (1997) original methodology, but found that although 3 year-old children performed well in the immediate test, the success rates dropped considerably after one-week and one-month delays (dropping by nearly 50%, from approximately 70% down to roughly 20%, with chance performance at 17%). Even following careful reviews of the literature (Horst & Samuelson, 2008; Holland, 2014) there does not seem to be a clear explanation for why words fast map sometimes, and not others. There are just too many differences in the methods used from one experiment to the next for a clear picture to emerge.

If fast mapping were a domain-specific word learning mechanism, it would also suggest that information other than words should not be fast mapped. Some theorists suggest that fast mapping is part of a more domain-general learning process (Markson & Bloom 1997; Bloom, 2000; Childers & Tomasello, 2002 & 2003). Examining this question, some researchers have investigated whether fast mapping can be used to learn alternative information beyond words. Markson and Bloom (1997), investigated 3 and 4-year-olds' (and adults') fast mapping of three kinds of information. Participants were introduced to a novel name, a linguistically presented fact (e.g., my uncle bought me this) and a visually presented fact (where a sticker is placed) about an artefact. All the novel information was presented in a game, whilst participants interacted with four familiar and six unfamiliar artefacts. They were tested after one of three intervals: immediately after exposure, after a one-week delay, or after a one-month delay.

Markson and Bloom found that the children (and adults) were still able to recall name and linguistic fact even after a one-month delay. After one month, only the adults had managed to retain the visual fact. They suggested a number of reasons for this. Firstly, that perhaps the novel artefacts themselves - being unfamiliar - were simply more salient than the relatively unimportant placing of a sticker. Secondly, that possibly fast mapping is only used when information can be extended to other category exemplars (i.e., names can be extended). The placing of a sticker would not be relevant to other members of a similar category and thus not retained under by fast mapping conditions.

A study by Deák and Toney (2013) aimed to replicate and extend these findings. However, despite the authors' defining the investigation as fast mapping (using minimal exposure and testing long term retention), the procedure included explicit naming. For example Deák and Toney explicitly told the children that they would learn about some new objects and they should try to remember what they learn. As such it cannot be considered fast mapping, under my definition (incidental learning, minimal exposure, and long term retention). Deák and Toney similarly tested children's ability to rapidly learn novel artefact names; facts using familiar language (e.g., 'my sister gave this to me'); and facts containing a novel word (e.g., 'this is from Saybu'). Additionally, they tested whether or not children were able to learn an association between a novel artefact and visual information (as has previously been tested with sticker placement tasks), but this time in the form of pictograms (e.g., do not enter sign). For pictogram learners, the experimenter held the artefact whilst pointing to a pictogram card stating, "This one goes with this".

Deák and Toney found that after a week's delay, 3- and 4-year-olds were able to pass comprehension tests in all four conditions. Specifically, children were able to select target artefacts from an array of 17 familiar and unfamiliar items, for example: "Can you find an *Oni*?" (word/name condition) or "Which one is from *Saybu*?" (fact condition). In the pictogram condition, the experimenter pointed to a card and asked, "Which one goes with this picture?"

Participants were also successful in completing extension tasks. Children were shown 20 artefacts; the original four novel artefacts and four additional category exemplars. Of the four different exemplars: one was identical (i.e., same shape, colour, and texture), another was the same shape but a different colour, a third was the same shape but different texture and colour and the final artefact was a different shape and different colour. Children were prompted to look at all the artefacts and then asked: "Are there any [name]s, can you find all the [names]s?". Once children had selected an artefact they were asked, "Are there anymore [name]s, or is that the last one?" Until the children replied "No", or all the artefacts had been selected. This was replicated for facts: "Are there any things here that [fact]?" and pictograms, "Are there any [picture card raised]?" In all three conditions children were able to extend appropriately. However, after a week's delay, children scored higher comprehension, production and extension accuracy for facts (particularly those containing a novel word) over novel names and pictograms.

Several other studies also report young children's ability to learn non-verbal information such as melodic sequences or actions (Campbell & Namy, 2003; Childers & Tomasello, 2002 & 2003). However, these studies also do not meet my definition of fast mapping, as at least one of my three criteria (incidental learning, minimal exposure, and long term retention) were not met. Most commonly, as in the aforementioned Deák and Toney (2013) study, it was incidental learning that is missing.

1.3.4 The 'Not Quite' Fast Mapping of Artefact Action and Function

Similarly, there has been some research to specifically investigate children's learning of artefact information for use. As noted in the first section to this thesis, to successfully *use* an artefact in an adult like fashion, we need to know the name, action and function associated with it. We have evidence from word learning studies that, at least sometimes, children are successful at fast mapping artefact names (e.g., Heibeck & Markman, 1987; Holland, Simpson & Riggs, 2015).

Some research suggests that children will use a mutual exclusivity approach to children link a novel verb to a novel action (Merriman, Marazita & Jarvis, 1995; Merriman, Evey-Burkey, Marazita & Jarvis, 1996). These studies did not claim to be examining fast mapping (as they used explicit exposure and tested immediately) but, after brief exposure, children match a novel action to a novel verb. However, these were still verbal representations, and as such ultimately investigating language acquisition. Is it possible that children can also fast map action and function? There are several relevant studies worth considering (Childers & Tomasello, 2002, 2003; Hahn & Gershkoff-Stowe, 2010; Casler and Kelemen 2005). Although none meet my definition of fast mapping, and indeed, the authors only talk about 'learning'.

The first to investigate children's learning of artefact actions were Childers and Tomasello (2002). This study investigated how the number and frequency of exposures affected children's learning. Children were taught either six novel words (six nouns or six verbs) or six novel actions through *ostensive* labelling of a novel artefact. This exposure was then repeated under different training timetables (e.g., four exposures in one day or one exposure per day for four days). Although individual exposure was brief and children were tested after a delay period, the demonstrations were both explicit and repeated several times (more than one exposure session) and as such fail to meet all three fast mapping criteria.

Children were tested on both comprehension and production. With comprehension, children were very good at recalling the target artefact in all word and action conditions. They accurately retained on average 2.7 out of 3 nouns, 2.4 out of 3 verbs, and 2.6 out of 3 actions – with no significant differences between conditions. However, with production, children were able to reproduce novel actions (2.08/3) significantly more than they were able to reproduce novel words (nouns 1.18/3, verbs 0.63/3). It was also noted by the authors that children in the verb condition often reproduced the manual behaviour for the verbs action when asked to speak the word.

Childers and Tomasello (2002) suggest their results indicate that the cognitive processes children use to learn words can be applied to the acquisition of actions. They make two proposals. First they suggest that children strive to learn information that they are not able to determine by simply looking at an artefact. The action associated with using an artefact cannot usually be inferred directly from its appearance (especially by children with their limited knowledge of the physical world). Instead these actions are often learnt socially, through observation. A second proposition is that children strive to learn information about a category that is relevant across other exemplars from that category. Thus children understand that the action associated with an artefact will be performed with all exemplars of that artefact category.

Childers and Tomasello (2003) found evidence for the extension of artefact-actions in a follow-up study. Adapting the method of Waxman and Booth (2000), they compared $2^{1}/_{2}$-year-olds' learning and extension of artefact names. Children were shown seven artefacts (four familiar and three novel). The experimenter picked up each artefact commenting on a feature of it before putting into a bucket. When referring to the target artefact in the word condition the experimenter said, "It's called a Koba". In the action condition she demonstrated an action on it (balancing it on her elbow and moving the elbow up and down) whilst saying, "Look what we can do with it". Although slightly less explicit than in the 2002 study, this still cannot be regarded as incidental exposure.

Once all the artefacts had been acted upon and then placed in the bucket, the experimenter tipped all of them back onto the table. Participants were then asked an initial comprehension question. This was either "Can you hand me the koba?" or "Can you pass me the one we do this with?" [pantomiming action]. Immediately following this, with no delay period, children were shown a new set of artefacts including 2 novel exemplars that were the same shape (but differed in size, colour or texture). They were then asked the extension question "Are there any other ones that are kobas?" or "Are there any more we do this with?" The question was repeated until children said no, or had selected all of the items. Naturally, with explicit exposure I would not describe this procedure as fast mapping, moreover, with no delay period, nor have the children demonstrated learning, only extension.

Across both naming and action conditions, 12 out of 20 children selected only within category artefacts and 8 out of 20 selected both within category (same shape, different size / texture / colour) and out of category (different shape) novel exemplars. However, on reflection, the authors suggested that children of this age probably struggled to say no to the experimenter, so they then analysed only the first two responses made on the extension trials. Sixteen out of 20 children, in both the action and naming conditions, successfully identified the two-novel exemplars in their first two responses. In Childers and Tomasello's opinion, these two studies support the view that children can learn novel actions as easily as names.

The final article, which investigates artefact-action learning, is Hahn & Gershkoff-Stowe (2010). Citing Childers and Tomasello (2003) data as the motivation for their work, they aimed to replicate the previous results in young children, and see whether the same outcome was found with older children and adult participants. Once again this study fails to meet my criteria for fast mapping as the novel artefacts were explicitly named and attention drawn to the action made with them. In Experiment 1, 2- and 3-year-olds were shown four novel artefacts, presented individually. In the naming condition, the experimenter named the artefacts approximately six times, and in the action condition the experimenter demonstrated an action six times. The children were permitted to handle the artefacts, and were encouraged to produce the names or actions for themselves. Immediately after the exposure session, children were assessed on their comprehension and production.

In the comprehension test children were shown the four novel artefacts and asked to identify each one in turn. For the noun condition children were asked "Where's the [name]?" In the action condition the experimenter re-enacted target actions asking, "Which one do we do this with?" The 3-year-olds passed comprehension tests successfully in both the action and naming condition. The 2 year-olds found the comprehension of name slightly easier than the comprehension of action. In the production tasks the children were passed each artefact one at a time and either asked "What's this called?" or "What do we do with this one?" However, whilst being able to successfully reproduce the action (Mean = 85.15%), most children were unable to reproduce the name (Mean = 11.71%).

Building upon this, Experiments 2 and 3 tested older participants with larger numbers of novel artefacts, and a second testing session the following day. Four- and 5-year-olds were able to comprehend more names than they could produce across both sessions. However, the action data did not display the same production deficit. By the second session, a significant number of participants could successfully both comprehend and produce all actions, but could not produce more than half of the names.

We know from the sheer scale of human vocabulary that children are extremely proficient at learning new words. Previous research suggests fast mapping is a successful mechanism for learning new words, particularly artefact names. Directly comparing artefact name and action learning, we can see that children were equally, if not more, successful at learning an artefacts action under these conditions. This certainly suggests that, even under a strict fast mapping procedure, children would be capable of fast mapping artefact action information.

Casler and Kelemen (2005) investigated artefact function learning. They suggest that children as young as 2-years-old are able to successfully learn function information after minimal exposure. Participants were presented with two novel artefacts both of which afforded the demonstrated function. However, only one of these artefacts was used to achieve this function. Tested immediately after exposure, both children and adults were more likely to choose this target artefact when asked to achieve the demonstrated function (even when a different exemplar was used or selecting it required effort). Investigating further, participants were asked which tool they would use to achieve a *different* function. Although children chose the target artefact less often when asked to achieve this new function, only the adults consistently chose the other artefact (i.e., above chance).

Despite the aforementioned studies (Childers & Tomasello, 2002, 2003; Hahn & Gershkoff-Stowe, 2010; Casler & Kelemen, 2005) not adhering to my definition of fast mapping, they do provide evidence that children are able to learn artefact actions and functions from relatively limited exposure. I consider some of the limitations of these studies in the Introduction to Chapters 2 and 3, when explaining the method I employ to investigate the fast mapping of artefact knowledge.

1.4 How We Learn About Artefacts? Imitation Research

1.4.1 What Do Children Learn When They Imitate?

Imitation research (e.g., McGuigan, Makinson & Whiten, 2010; Simpson & Riggs, 2011a; McGuigan & Whiten 2009) commonly investigates children's ability to reproduce an action after a limited exposure. Some of this research requires children to act with a tool (i.e., an artefact) to achieve a goal (i.e., to achieve the artefact's function – e.g., McGuigan, Makinson & Whiten, 2010; Simpson & Riggs, 2011a; McGuigan & Whiten 2009). Under experimental conditions, imitation research consistently finds that through observational learning, children are quick to imitate the actions of others (e.g., Carpenter, Call & Tomasello, 2005; Nielson, 2006). Imitation is recognised as "…an effective mechanism for novices to learn object-related skills" (Brugger, Lariviere, Mumme & Bushnell, 2007; p 807). With participants in many studies ranging from one to five years, it would suggest that as a learning process, imitation starts early and develops rapidly (Brugger et. al, 2007; Call, Carpenter & Tomasello, 2005; Rakoczy, Tomasello & Striano, 2005).

Imitation is generally defined as copying the actions of another. It has been documented that in imitation tasks, children will sometimes imitate actions regardless of whether these actions seem to be achieving something worthwhile. This unreflective copying (often called 'over imitation') has been demonstrated even when a task has a clear goal and when an action clearly has nothing to do with achieving it (Meltzoff, 1988b; Call, Carpenter & Tomasello, 2002; Horner & Whiten, 2005; Huang, Heyes & Charman, 2006; McGuigan, Whiten, Flynn & Horner, 2007). For example, in a task in which the goal is to use a tool to remove a sweet from a tunnel in a box, children will imitate an action that involves pointlessly waggling the tool in another part of the box. The explanations behind this behaviour vary. There are domain-specific accounts which suggest that children make use of their physical-causal knowledge (e.g., Whiten, McGuigan, Marshall-Pescini & Hopper, 2009) and social-cultural accounts, which focus more on children's thinking about their relationship to the to-be-imitated demonstrator (e.g., Over & Carpenter, 2012). More recent theories have emphasised the role of more domain-general cognitive abilities such as working memory (e.g., Simpson & Riggs, 2011; Subiaul & Schilder, 2014).

Whilst these imitation studies may sometimes provide insight into children's ability to learn about artefacts (including artefact action and function), it is important to note that these studies are not examining artefact learning. Imitation researchers usually do not focus on artefacts. Often the research requires the children to act upon 'objects' or 'tools' (e.g., Huang and Charman, 2005; Hayes, Ashford & Bennett, 2007; Leighton, Bird & Heyes, 2010), but these are simply as a means of created easily coded action. Whether or not these actions are being made with artefacts, and what children might infer about the artefacts being used, is largely irrelevant. Generally, imitation researchers' interest lies in explaining why children *perform some of the actions they observe, and not others*.

Nevertheless, imitation research often involves a specific action being performed with a specific artefact to achieve a specific goal - this can be inferred to represent the function of the artefact used (e.g., McGuigan, Whiten, Flynn and Horner, 2007; Simpson & Riggs, 2011; Horner and Whiten, 2005). In such experiments children are often able to reproduce the action to achieve the goal (function). For example, McGuigan, Whiten, Flynn and Horner (2007) used a puzzle box task in which children saw an experimenter use a long tool to retrieve a reward from the centre of a box. During the demonstration children saw the experimenter perform an irrelevant action (inserting the tool in the top of the box) and the relevant action (opening the door on the front to insert the tool) to retrieve the reward.

Three- and 5-year-olds, regardless of condition, all imitated the irrelevant action before completing the relevant actions to retrieve the reward. Thus, all the children did correctly demonstrate the function of the tool to retrieve the reward. Although it is unclear exactly what the children are learning with regards to the link between the tool, action and function, these results contribute further evidence that after brief exposures children are capable of successfully recalling actions demonstrated on an artefact. As these actions achieve a goal, such results can provide some support for the notion of rapid learning of function. Although as the irrelevant action is produced, children's causal understanding of the artefact's function can be questioned.

1.4.2 Imitation Literature Versus Fast Mapping Literature

It is clear that comparisons can be made between the fast mapping and imitation literatures. However, as expected with different literature, there are many procedural differences between the tasks used, as well as problems with terminology and conceptual frameworks that overlap in an ill-defined way. Reconciling the conceptual frameworks is beyond the scope of this thesis – I focus on the methodologies.

I maintain three criteria must be met for learning to qualify as fast mapping (incidental learning, minimal exposure, and long term retention). Of these three criteria, perhaps the most notable similarity between fast mapping and imitation studies, concerns the learning of novel artefact actions and functions following brief observation. Some imitation studies can be argued to involve the demonstration of an artefact's use under conditions of minimal exposure (e.g., McGuigan & Whiten, 2009; McGuigan et al., 2007). A brief exposure session involves the experimenter's performing a specific action with a tool (artefact) to achieve a specific goal (the artefact's function). Following brief exposure, children are tested to see what information they have retained. However, one difference is that imitation research *always* tests production, to see if children can *copy* the actions they saw. In contrast, fast mapping research usually tests comprehension (only on rare occasions is production tested).

Of the three criteria perhaps the most notable difference is that, unlike fast mapping, imitation research usually involves overt demonstrations of the novel information (e.g., Huang & Charman, 2005; McGuigan, Makinson & Whiten, 2010; although there are exceptions, e.g., Williamson & Markson, 2006). As mentioned, children are encouraged to watch the experimenter performing an action to achieve a goal, and are asked to 'have a go' themselves. This is arguably not representative of how most learning occurs in early childhood: usually young children receive *incidental* exposures to the information.

Finally, to truly demonstrate learning it is important to show retrieval of information after a delay period. On the whole, most imitation studies require participants to perform the actions they have seen immediately following the experimenter's demonstration. A study by Simpson and Riggs (2011) begins to bridge the gap between the immediate testing of an imitation task and the delayed testing period necessary for a fast mapping approach.

Using a puzzle box task (as previously described, used in Horner & Whiten, 2005; McGuigan, Whiten, Flynn & Horner, 2007; McGuigan & Whiten, 2009) 3- and 4-year-olds were shown a clear box with two apertures, one in the top and one in the front. Once again, the block could only be removed by inserting a tool into the front aperture; the top hole was seen by the children to not allow access to the block. The experimenter showed the children both an irrelevant action, followed by the relevant action. This demonstration was repeated three times during one exposure session. In the control condition children were simply given the apparatus to play with. Half the children were then immediately given a chance to have a try themselves, and the other half, five – eight days later.

Interestingly, Simpson and Riggs found children in the immediate condition usually performed the irrelevant action and always followed with the relevant action. However, children in the delay condition rarely performed the irrelevant action, and instead simply performed the relevant action to achieve their goal. Although direct learning, it appears that children were able to successfully map both a novel action and (arguably) a function to a novel artefact, and retain this information for later production. This study provides evidence that children can rapidly learn artefact information for use. The ability to recall and reproduce relevant (i.e. functional) over irrelevant actions after a delay has been demonstrated in infants as young as 12 and 18 months (Óturai, Kolling, Hall & Knopf, 2012).

Although it is a step towards what we are trying to research, we cannot be clear exactly what the children have mapped to the artefact used in the Simpson and Riggs (2011) study, to be able to draw any concrete conclusions. As Simpson and Riggs recognise themselves, it is unclear whether the children have successfully mapped the physical outcome of the box (i.e. the block being removed from it), the experimenter's goal in retrieving the block, the tool's function, or simply an experimenter's novel action. It would certainly be premature to conclude that children had successfully learned a relationship between the novel tool and the action made to produce its function. In contrast to imitation research, fast mapping research focuses very explicitly on the learning of a *specific link* between an individual piece of information (e.g., a word) and a particular category (e.g., a kind of artefact). So for example, what is learnt in Markson and Bloom's (1997) fast mapping study is a specific link between a novel word and a novel artefact. Whether or not children are making such links is largely ignored in imitation research.

1.5 What Do We Learn About Artefacts? Extension and Categorisation

In essence, fast mapping studies try to understand what the imitation studies do not: have children successfully learned a link between a novel artefact and the novel information for use (artefact name, action or function)? There are a number of questions fast mapping researchers ask at test to establish whether or not the participant have learned this link. As previously mentioned, I believe, in line with Carey and Bartlett's (1978) original research, that learning can only be demonstrated after a significant delay period.

After a delay, the majority of fast mapping studies use comprehension tasks as standard to test for learning. At test, the children are required to select the target artefact from a group of objects (Markson & Bloom, 1997; Spiegel & Halberda, 2011; Vlach & Sandhofer, 2012). Some studies have also tested production, asking children to reproduce the word by asking what the target artefact is called (Carey & Bartlett, 1978, Heibeck & Markman, 1987; Gershkoff-Stowe, 2002; Horst & Samuelson, 2008). These data suggest word production is much harder than word comprehension. Extension, in contrast, offers a more stringent test of comprehension. It provides evidence that children have linked a word to category, rather than just remembered something about an event they previously witnessed. In addition, examining what information children extend helps us understand what features they believe to be *characteristic* of that category.

1.5.1 Extension Tasks

Within fast mapping research, an extension task allows children to show what they have learned in relation to an artefact category (Childers & Tomasello, 2003; Deák & Toney, 2013). Researchers question whether children believe that the information learned is *only* relevant to the individual target item seen during exposure, or whether it can be *extended* to other examples from the same category. Making and retaining that word-category link is at the heart of vocabulary growth (Horst & Samuelson, 2008). Children who form this link are then able to extend the use of the novel word to new exemplars of the same category.

In an extension task children undergo minimal training to attach a novel name to a novel artefact. At test, children are shown some within-category examples of the artefact, matched for shape, but differing in colour, size or texture (see shape bias – section 1.2.9), and some between-category examples that do differ in shape. Children are then asked whether there are any other examples of the named category (Markson & Bloom, 1997; Waxman, 1999; Deák & Toney, 2013; Waxman & Booth, 2000). For example, Waxman and Booth (2000) investigated the extension of novel words and facts. The experimenter introduced 4-year-olds to ten items in a bucket (four familiar, six unfamiliar). She then, picked up the target artefact and either labelled it, "It is called a koba", or introduced a novel fact about it, "My Uncle gave it to me", and then replaced it in the bucket. Each of the remaining items were pulled out in turn and either named or a fact introduced. At the end of the training period, children were asked a comprehension question, (e.g., "Please can you hand me the one that is the koba?") to ensure they had correctly mapped the target artefact.

After a one-week delay, children completed three tests. In the first test the children were shown the original 10 items used in training, and the initial comprehension question was repeated. The children were then shown 13 new items: the original target artefact from the training set and two new exemplars of it; also two novel exemplars of each of the five remaining novel artefacts from the training set. The novel extension exemplars were the same shape as the target artefact but differed in colour, patterning, texture and size.

Children were presented with two extension tasks (order counterbalanced across participants). In the Yes/No task, children were presented each item in turn and asked, “Is this one a koba?” (or “Is this the one my Uncle gave me?”). In the Choice task the experimenter displayed all of the extension items at once asking, “Can you show me one that is a koba?” Once a choice had been made, the experimenter asked: “Are there any other ones that are kobas?” This was repeated until the child said no, or all of the 13 artefacts had been chosen.

Waxman and Booth (2000) reported that even after a one-week delay, children were able to successfully extend the novel name correctly onto the new target exemplars while excluding others items. This study suggests that the children haven't just attached the novel word to one target item, but understood that this word was appropriate for all examples of the novel category. In contrast, children did *not extend* novel facts about in the same way – suggesting that extension applies to word but not verbally presented facts. However, there is a potential limitation of Waxman and Booth conclusion that facts are not extended. It may be that the *kinds* of fact they used do not logically extend to other category members (Bloom & Markson, 2001). For example, your uncle may have bought you a pen, but naturally that does not mean that all pens in the world have been bought by your uncle.

In the previously mentioned (Section 1.3.3) Deák and Toney (2013) article, children were able to attach facts (some containing novel words) as well as labels and pictograms to novel artefacts. Deák and Toney’s ‘facts’ did not seem any more extendable (as per Bloom & Markson’s assertions) than the original Waxman and Booth’s facts (e.g., “This one came from Saybu” or “My sister gave me this one”). Yet, at test, children were able to extend these facts (using both familiar and unfamiliar language), artefact labels and non-lexical information (in the form of pictograms) onto new, within category exemplars. Contrary to Waxman and

Booth (2000), these data suggest children do sometimes extend seeming 'un-extendable facts'.

Studies examining the rapid learning of artefact function and action (Section 1.3.4) have also tested for extension. Childers and Tomasello (2003), following Waxman and Booth's (2000) methodology, investigated the extension of words and actions in 2-year-olds. They found that children were able to rapidly learn novel artefact actions. Additionally, the children were also able to extend novel artefact actions to other within-category exemplars. This suggests that young children understand that an artefact's action can be constant across all category members. Likewise, Casler and Kelemen (2005) observed extension during their test of artefact function learning. During the comprehension trials at test, participants were shown the target artefact and one other. They were asked which artefact they would use to achieve the previously demonstrated function. Both children and adults repeatedly selected the original test artefact. During extension trials, they selected novel within-category exemplars to achieve the same function.

Overall, these studies suggest that children can extend all three types of artefact information for use: name, action and function. Potentially, children can see this information, as both intrinsic and enduring. As such, name, action and function become reliable features of an artefact's category, which are consistent across all category members. However, although this gives us an insight into children's understanding of an artefact's characteristic features, these tasks do not necessarily demonstrate which features children believe *define* category membership. That is, we do not know which of these features *must* be true for an artefact to belong to a specific category. Categorisation tasks can do this by requiring children to make rapid, online decisions about category membership.

1.5.2 Categorisation Tasks

Categorisation tasks are designed to investigate which features children use to define a novel category (Landau, Smith & Jones, 1988; Kelemen, 1999; Graham & Diesendruck, 2010; Deák, Ray & Pick, 2002). These categorisation tasks can involve judgements of a more perceptual, or conceptual nature. A task investigating perceptual judgement, is similar to the extension procedure describe above. Differences are that it requires no learning, but instead has far more trials. Landau, Smith and Jones (1988) investigated how 2- and 3-year-old children (and adults) categorise of a large number of items varying in colour, size, shape and texture. Participants were shown a novel artefact and told its name. This artefact was then placed in view, and participants were then either given a yes/no test or forced choice test of further items. In the yes/no procedure, participants were shown seven test items, one by one, and asked, "Is this a Dax?" In the forced choice procedure, participants were shown pairs of artefacts and asked, "Which of these is a Dax?" This allowed researchers to gauge how the different features were ranked relative to one another. Landau, Smith and Jones found that of these features (colour, size, shape and texture), children and adults were biased towards shape. Moreover, this appeared to increase in strength between the ages of 2- and 3-years-old.

A more conceptual investigation examines how children respond to artefacts that perform the same function, but have different shapes. When learning new artefact labels, should the label extend to other artefacts of the same shape or those that perform the same function? The argument surrounding this research question, and how children learn to extend artefact names, began in the 1970's. Historically, Clark (1973) proposed that, when naming novel artefacts, children attend to shape. Nelson (1973) put forth the opposing view, that children's initial word meanings are predominantly based on dynamic, functional information.

In one of the first studies to examine this, Gentner (1978) tested children from 2½-years-old up to adults with two different artefacts: a 'jiggy', which made funny faces when a lever was depressed; and a 'zimbo', which dispensed jellybeans when a similar action was performed. The artefacts looked different, and performed different functions, but the action was the same. They were shown a third item which had the outward appearance of a jiggy, but instead of changing faces, it dispensed jellybeans like a zimbo. Participants were then asked what this third object was called. Children from 2½ to 5 years tended to categorise by shape. Children from 5 to 15 years preferred function. Many adults attempted to give it a hybrid name, such as 'jiggy-zimbo', but when pushed, were more likely to respond based on shape- this adult finding has not been replicated in subsequent categorisation research with adults (e.g., Diesendruck, Hammer & Catz, 2003).

Studies such as Gentner (1978) and Landau at al. (1988) provided the first evidence for a shape bias. This shape bias can be described as young children's preference to categorise novel artefacts by their shape. This is largely well established and robust finding in the literature (Graham & Diesendruck, 2010; Deák, Ray & Pick, 2002; Graham, Williams & Huber, 1999; Landau, Smith & Jones, 1988). Two main theories have been proposed to explain the shape bias (for reviews see Keil, 2008; Elman, 2008). This has continued for the last 40 years, remaining largely unresolved today. I am not claiming to do so now, I will however set out some of the key features of each theory and some of the arguments used to support them.

1.5.3 Attentional Learning Account (ALA)

Smith and colleagues propose an Attentional Learning Account (ALA) of the shape bias (Smith, Jones & Landau, 1996; Landau, Smith & Jones, 1998; Samuelson & Smith, 1999; Smith, Jones, Yoshida & Colunga, 2003). The ALA describes learning mechanisms, which come into play at around two years of age, when children begin a ‘vocabulary spurt’. It is during this second year that the shape bias is said to develop. Smith and Samuelson (2006), make three main claims. First, a child’s learning environment presents correlations between object properties and object categories. Young children are exposed to many count nouns, often regularly repeated (e.g., ball, cup or chair). Children learn that these nouns tend to refer to rigid, solid things. Smith and colleagues (Smith, Jones, Landau, Gershkoff-Stowe & Samuelson, 2002) describe this as the first step in a four-step model, which demonstrates how children learn object names (and thus more specifically, artefact names), and proposes a name-shape correspondence that is bi-directionally and causally related. This learning of individual artefact names sets up step two. Children then begin to understand that the same noun tends to refer to artefacts of the same shape (Samuelson & Smith, 1999; Jones & Smith, 2002; Colunga & Smith, 2005). For example cups are cup-shaped and balls are round. This second step is described as a first-order generalisation (Smith et al., 2002).

Step three describes a second-order generalisation, that artefact names generally label categories of similar shaped things. This is the ALA’s second claim, that when learning a name for a novel artefact, this understanding begins to direct children’s attention towards shape. As children attend to shape more regularly, they begin to infer that an artefact’s shape determines its name. Thus, artefact names denote an association between words and perceptual features. The third claim, and final step of higher-order generalisation, is that as this association grows, children are able to use this as an automatic and non-strategic mechanism to allow them to categorise novel artefacts by their shape. Past learning, activated by contextual cues, directs attention to just the right property (shape) and as such children can now rapidly learn and extend the name for novel artefacts and their categories (Smith & Samuelson, 2006).

Smith, Jones, Landau, Gershkoff-Stowe and Samuelson (2002), gave 17-month-olds seven weeks of training during play sessions. During this play, infants were introduced to a novel artefact, which was given a novel name. A second item was also introduced, that was the same shape but differed in colour, size or texture – and was also labelled with the novel name. A third item was introduced, which differed in shape but matched either the colour or texture of one of the target artefacts, but the experimenter dismissed this as not a [novel name]. After eight weeks, children were shown an original target artefact, labelled with its novel name, and then asked to pick another from a choice of three further items. One matched in shape, one matched in colour, and one in texture. Children extended the novel name via shape 88% of the time. In week 9, children were tested with new exemplars and new names, and continued to extend these novel name using shape 70% of the time. Finally, parents completed vocabulary checklists on week 1 and week 8. Children in this training condition showed a greater increase in their productive vocabularies than a control group.

Smith and colleagues (2002) proposed these data support an ALA because, they suggest, the more children learn about the association between artefact names and shapes, the more automatic this learning becomes. After training children to attend to shape, not only did it encourage them to attend to shape when extending novel names in a laboratory environment, but it also dramatically increased their learning of artefact names in their everyday lives. As the association between names and shapes develops the learning mechanism becomes more automatic, allowing young children to successfully learn more object names, and to successfully extend this across same shape categories. Supporters of an ALA believe that the shape bias is specific to language acquisition, and more specifically still, to artefact naming (Jones, Smith & Landau, 1991).

The ALA also proposed that, due to a core mechanism providing top-down control of attention, more conceptual information (e.g. artefact function), has little to no effect when naming artefacts. Furthermore, ALA suggests that when put in direct conflict with one another, children categorise by shape and will ignore other characteristics such as size, colour, texture and function. ALA proponents cite a variety of studies that suggest that children categorise by shape while adults categorise by function (e.g., Smith, Jones & Landau, 1996; Landau, Smith & Jones, 1997; Graham, Williams and Huber, 1999).

1.5.4 Shape-as-Cue Account (SCA)

An opposing theory to the ALA, proposes that category formation and learning about artefact kinds is a much more conceptual process (Bloom, 2000; Ware & Booth, 2010). The Shape-as-Cue Account (SCA) suggests that shape cues artefact categories, because artefacts with the same function usually have the same shape. Like ALA theorists, they think children use shape to determine the category to which an artefact belongs, BUT only because shape reflects function. When discussing children's categorisation of artefacts, Bloom (2000) argues that we should not simplify the debate as perception versus conception; it is not simply a matter of shape versus function. Taking inspiration from philosophical theories of essentialism (Locke, 1960), Bloom (2000) describes the SCA as a theory which suggests children categorise artefacts by shape because it cues the functional intentions of the artefact's designer: its essential reason for being created.

For real–world artefacts, the relationship between their appearance and their intended functional is often transparent. Literature discussing functional understanding often speaks of affordances, where the physical shape of an artefact gives clues to its functional capabilities (Michaels, 2003; Symes, Ellis & Tucker, 2007). With regards to categorisation of artefacts, Bloom (2000) uses the example of a chair to illustrate that when labelling a chair we do not simply judge that it looks like other chairs we have experienced. More precisely, we evaluate whether it appears to have been created with the same intentions as other chairs we have experienced.

Numerous studies have suggested that children regard function as central to an artefact's identity. Evidence is striking, even in young children. Studies, particularly by Kemler Nelson and colleagues (Kemler Nelson & Students, 1995; Kemler Nelson, Frankenfield, Morris & Blair, 2000; Kemler Nelson, Russell, Duke & Jones, 2000), indicate that when functions are clear and plausible, even 2-years-olds will categorise by function rather than shape. There is also evidence to suggest that children can categorise artefacts by the designer's *original* intended function, rather than by their current use (Kelemen, 1999; Diesendruck, Markson & Bloom, 2003; Jaswal, 2006; Defeyter, Hearing & German, 2009). Furthermore, children demonstrate an understanding that a broken artefact, which is functionally impaired, still belongs in the same category – presumably because its intended function is unchanged (Kemler Nelson, Herron & Morris, 2002; Kemler Nelson, Holt & Egan, 2004).

Ware and Booth (2010) suggest that, for children, learning function information facilitates categorisation by shape. Also proposing a stepwise process, they provide a more conceptual description of how intended function and the shape bias are related. Firstly, children's direct experiences with artefact functions allow them to distinguish artefact categories. Ware and Booth (2010) use the example of spoons and forks. The labels 'spoon' and 'fork' describe two similar artefacts (e.g., similar overall shape, material, and action). However spoons are used for mashed or liquid food, whereas forks are for eating solid foods. Next, this attention to function allows children to notice functionally relevant properties (i.e. a spoon has a concave head for holding liquid, whereas a fork has tines for securing solids). This attention to these functional features allows them to identify the relevant shapes associated with these properties, thus enabling identification and extension to new category members. Finally, this repeated recognition that 'shape denotes function' lead to a general assumption that shape is a useful cue when organizing artefact categories. Shape is particularly useful, when more reliable, but perhaps more subtle properties, are not immediately clear.

Ware and Booth (2010) tested this theory, replicating Smith et al. (2002), except that children were trained to attend to function, rather than shape. During training sessions, 17-month-olds were given extensive experience of four pairs of similarly shaped artefacts performing the same function (a control group were also given the artefacts to play with, but did not have their functions demonstrated). As with Smith et al. (2002), a third artefact was introduced; differing in shape, but matching either the colour or texture of one of the test artefacts. The experimenter commented that this artefact could not perform the same function as the other two, "Oh look! I can't do that with this one", and put it away. When tested on the trained-artefacts children in both the functional-training and control groups categorised by shape.

In a further test, children were shown four new artefacts: a target artefact, a shape match, a colour match, and a texture match. Participants did not observe the function of any of these new artefacts. Children were then asked to select one of the three artefacts to match the target. The functional-training group selected the shape-matched artefacts significantly more often than the control group (who performed no different to chance). These data suggest that children had learned the importance of shape during the functional-training, leading them to categorise the new artefacts by shape. Booth and Ware (2010) concluded that these data corroborate the SCA: they suggest that learning about function promotes the understanding that shape is a reliable cue to category membership.

The SCA is compatible with the proposal that young children adopt the design stance. The design stance suggests children understand that artefacts are intentionally created with a particular purpose in mind (Dennett, 1987; German & Johnson, 2002). They may also understand that their shape is the product of intentional design. As with an ALA, researchers supporting a SCA believe that children's level of understanding improves with age. However, this is because although children are able to grasp some threads of a design stance (e.g., artefacts intentionally created by humans, or can be categorised by functions rather than appearance), they have not yet fully understood that each artefact is 'made intentionally for this singular purpose' (German & Johnson, 2002).

This explains why ALA researchers, when placing shape and function in conflict, can find evidence of children using shape to categorise novel artefacts (Smith, Jones & Landau, 1996; Graham, Williams & Huber, 1999). Firstly, proponents of SCA claim that ALA studies use poor examples of function in their experiments. When the function is unclear, or more specifically when the relationship between the function and its perceptual properties are unclear, it forces participants to revert back to shape-as-cue for categorisation. This is exacerbated in younger children whose understanding of design is still 'shaky'. The SCA clearly recognises the importance of shape to category membership. However, the account proposes that when placed in conflict, if the function information is clear, it can override shape as the *defining feature* of category membership (Kemler Nelson, Russell, Duke & Jones, 2000; Kemler Nelson, Frankenfield, Morris & Blair, 2000, Kemler Nelson, 1999).

Finally, in opposition to ALA claims, the SCA proposes that shape can be a category cue either when an artefact is named or simply when asked to categorise it. A feature of the SCA is that a shape bias is not specific to verbal labelling (Diesendruck & Bloom, 2003). Diesendruck and Bloom (2003) asked children to select within-category exemplars from a group of novel artefacts to match a novel target. In the naming condition children were asked, “Which one of these is also a patoo?” In the kind condition, children were asked, “Which one of these is the same kind [pointing to a novel target]?”; in the goes-with condition children were asked, “Which one of these goes with this [the target]?” Diesendruck and Bloom found no differences between the three conditions. According to a SCA interpretation, this is because shape is a cue to an artefact’s function, not its name.

1.5.5 The On-going Debate: ALA versus SCA

As one might expect when two conflicting and, as of yet, largely unreconciled theories dominate in a literature, the precise details of the tasks used become critical. When examining shape versus function categorisation in forced choice tasks, ALA supporters report that young children (2- to 4-year-olds) categorise artefacts based on shape (Gentner, 1978; Smith, Jones & Landau, 1996). These results can seem definitive, as even when children are given lots of function information, they still categorise by shape (e.g., Graham, Williams & Huber, 1999). Often SCA supporters contend that the function information was not *sufficiently* clear (e.g., Kemler Nelson et al., 1995; Kemler Nelson, 1999). Consistent with this, there are studies which suggest that, when functions are sufficiently clear, and there is no time pressure to answer, children categorise artefacts based on function not shape (Kemler

Nelson et al. 1995, Kemler Nelson 1999, Kemler Nelson, Russell, Duke & Jones, 2000; Kemler Nelson, Frankenfield, Morris & Blair, 2000). More recently, Booth, Schuler and Zajicek (2010) report that artefact function information facilitates early categorisation in infants as young as 16-months-old.

Although there is debate regarding children's early categorisation, researchers do agree that older children (5- to 7- years-olds) rely increasingly on function, and are more adult like in their categorisation of artefacts. For example Diesendruck, Hammer and Catz (2003) examined how children and adults map categorical similarities in novel artefacts. Children were presented with a computer generated target artefact, and then shown a further 10 images. The level of physical or functional similarity varied, to see at what point children (and adults) would reject further exemplars as no longer belonging to the same category as the target. Diesendruck et al. (2003) found the 4- to 5-year-olds used both shape and function similarity, rejecting exemplars with either a high physical or high functional dissimilarity. Whereas, adults focused more clearly on function (Diesendruck, Hammer & Catz, 2003; Hammer & Diesendruck, 2005).

Functional fixedness literature is also consistent with children's increasing recognition of the importance of function to artefact categorisation. Using problem-solving tasks requiring children to inhibit a familiar function to achieve a new goal, Defeyter and German (2003) indicate that children's concrete functional one-to-one correspondence isn't fully developed until approximately 7-years-old. This will be discussed more in Chapter 4.

The conflict between ALA and SCA theorists is on-going (Cantrell & Smith, 2013; Augustine, Smith & Jones, 2011; Booth, 2014; Kemler Nelson, O'Neill & Asher, 2008; Ware & Booth, 2010). Both sides of the debate seem unwilling to recognise the possible significance of the findings of the other. Or, perhaps more frustratingly, just re-interpret the results in a fashion that then supports their own argument (e.g., Smith & Samuelson, 2006). I shall not be 'taking sides' in this debate, however in Chapter Four I suggest that the role of action in categorisation has previously been overlooked, and investigate the relative importance of action, function and shape in artefact categorisation.

1.5.6 Differences Between Extension and Categorisation Tasks

Although extension is linked to categorisation, it is important to remember that categorisation and extension studies are actually asking different questions. As such, they give us slightly different insights to what children understand about artefacts. Delayed extension tasks test *learning* about artefact features. They test which information children remember as being consistent with belonging to a previously encountered artefact kind. For example, if children extend by artefact action, we can conclude that, for them, action is a memorable marker of category membership. The target and new exemplar are usually similar in appearance. They have the same shape and only differ in ways that humans of all ages often regard as trivial – that is they are a slightly different size, or different colour or have a different texture. Thus the level of conflict between features (e.g., shape versus size) is small.

In contrast, categorisation tasks tend to require more theoretical judgements under greater conflict. After all, these tasks try to determine what feature *defines* category membership. Usually, in a forced choice procedure, participants are asked to make an immediate, online decision regarding which test artefacts are the same as the target. Children are asked to make an immediate judgement of which one of two conflicting characteristics determines category membership. In these situations we are asking a tougher question: perhaps the most fundamental question about category membership. What defines a category: what makes a spoon a spoon? Categorisation tasks often put into conflict two features that we know can be used as markers of category membership (e.g., shape and function, Gentner, 1978; Graham, Williams & Huber, 1999; Landau, Smith & Jones, 1996; Kemler Nelson, 1999) or even previous function and current function, Asher & Kemler Nelson, 2008; Chaigneau, Castillo & Martinez, 2008; Diesendruck, Markson & Bloom, 2003). As a result, there is no easy answer.

1.6 This Thesis

I have defined the information required to successfully *use* an artefact: its name (verbal label), its action (the way it is held and manipulated) and its function (the outcome of the action performed with it on a substrate to create change or achieve a goal). There is currently limited research on how children learn action and function, and whether the same processes that underpin the acquisition of artefact names are used to learn artefact action and function as well. In the real world, I assume that children are not overtly taught about most of the artefacts they encounter. Children are simply 'around' when others (usually adults) are using artefacts. In order to learn the names, action and functions associated with them, they must acquire this knowledge from their casual observation of artefacts being used and talked about.

Fast mapping seems the ideal cognitive process for learning artefact information. According to the original stringent definition I use, it requires brief exposure, no explicit teaching, and leads to a long lasting memory. While previous studies have investigated the learning of artefact action and function (Childers and Tomasello, 2002, 2003; Hahn &

Gershkoff-Stowe, 2010; Casler & Kelemen, 2005, 2007), none have met this stringent definition.

With regards to empirical observations of incidental learning of artefact information for use, there are examples of the different elements being learned separately. There are word-learning studies demonstrating children's ability to learn a novel artefacts name using a real world, fast mapping approach to learning (Heibeck & Markman, 1987; Markson & Bloom, 1997; Waxman & Booth, 2000; Horst & Samuelson, 2008; Deák & Toney, 2013). A few studies have examined the rapid learning and retention of artefact action (Childers & Tomasello, 2002, 2003; Hahn & Gershkoff-Stowe, 2010). A couple have investigated rapid learning of function (Casler & Kelemen, 2005; Casler 2014). Childers and Tomasello (2002, 2003) and Hahn and Gershkoff-Stowe (2010) report that children can rapidly learn a novel artefact's action. However, the demonstrations in these studies were both purposeful and overt. Casler and Kelemen (2005) demonstrated children's rapid learning of artefacts function, however did not test if this information was retained after a delay. Alongside these articles, imitation studies (e.g., Simpson & Riggs, 2011) also find that children are able to rapidly learn and demonstrate retention of novel artefact action (and perhaps function) – but again, following overt demonstration.

Combined, these studies suggest that children may be capable of learning artefact action and function using a stringent fast mapping methodology. As of yet, no single study has produced a methodology using all three factors simultaneously (brief, incidental, long term). This is what I aimed to do in six experiments of Chapters Two and Three.

Finally, I have discussed categorisation, and the conflicting theories used to explain the presence of a shape bias in children. The ALA (proposed by Smith & colleagues: 1988, 1996, 1998, 2002, 2003, 2006, 2008) suggests that early noun learning teaches children to attend to shape when categorising novel artefacts. An artefact's shape and name are associated. This attention to shape develops into an automatic mechanism, which allows children to learn new artefact names and create new categories (Smith et al., 2002). The SCA argues that children attend to shape as it is proven to be a relevant cue for an artefact's function. In this account an artefact's function defines its name, but its shape is a reliable marker of that function. This account suggests that we categorise artefacts by function, but when obvious functional information isn't available, children will rely on shape (Bloom, 2000; Diesendruck & Bloom, 2003; Kemler Nelson & colleagues, 1995, 1999, 2000, 2002, 2004). In Chapter Four I test whether children and adults use function or shape to make category judgements using a procedure developed in Chapter Three.

The Next Chapter

The next chapter describes Experiments 1 to 3. Experiment 1 compares children's referent selection when hearing a novel word or seeing a novel action. Experiment 2 employs a stringent fast mapping methodology (incidental learning, minimal exposure, long term retention) to directly compare artefact action and word learning. Furthermore, Experiment 2 examines whether children extend artefact actions and words to novel exemplars. Experiment 3 investigated the specificity of the action mapped. Exposure was identical to that in Experiment 2, however at test, children were shown a new action. All the data are consistent with the proposal that children map action to artefacts in the same way that they map words to them.

Chapter Two

Parallels in the Cognitive Processes that Map Names and Actions to Artefacts

Some of the methods and data that appear in this chapter have been published in Riggs, K. J., Mather, E., Hyde, G. & Simpson, A. (2015). Parallels between action-object mapping and word-action mapping in young children. Cognitive Science, DOI: 10.1111/cogs.12262.

2.1 Introduction

It is important to understand proposals for real-world word learning, before we are able to examine real-world learning of artefact information for use. Gentner (1983) noted that in many different languages, artefact names were the most common type of word found in early infant vocabularies (re-examined and confirmed by Mervis, 1990). As an artefact's name is one of three key components for information for use, is it possible that children are able to use the same learning processes to learn an artefact's action and function? Having touched upon some assumptions of word learning in Chapter One, I will discuss them in more detail here, suggesting how these processes could apply to artefact action learning.

2.1.1 Principles of Word Learning

As previously noted, children are able to learn huge numbers of words without direct teaching. Before children reach 12-months-old they have often begun acquiring the names of commonplace artefacts (Bergelson & Swingley, 2013). There are a number of explanations as to how this rapid word learning is possible. One school of thought is that language has its own unique, domain specific, learning processes. As outlined in Chapter 1, Markman (1990) proposed a number of word learning assumptions including whole object bias and a mutual exclusivity principle. In another key article, Golinkoff, Mervis and Hirsh-Pasek (1994) define a series of domain-specific lexical principles used to label artefacts. They propose two tiers in the development of six principles, which children use to learn novel words. I will briefly explain the three principles I feel are specifically relevant when considering how children learn artefact information for use. Firstly, in the lower tier and thus an earlier developing principle, Object Scope. Golinkoff and colleagues (Golinkoff et al.,

1994) ‘object scope’ principle suggests, much like Markman's whole object bias, that novel words are assumed to refer to whole objects, and not one of its parts or attributes. This whole object principle is proposed by many researchers, and so is widely supported (McNamara, 1982; Mervis, 1987; Markman and Wachtel, 1988; Gleitman, 1990; as cited in Golinkoff, Mervis & Hirsh-Pasek, 1994).

The second principle of interest, as detailed in Golinkoff, Mervis and Hirsh-Pasek (1994), was first proposed by Mervis and Bertrand (1993): the Novel Name-Nameless Category Principle (N_3C). The N_3C principle suggests that children will automatically attach a novel term to a novel, whole object that does not already have a known name. It posits that upon hearing a novel name, we actively seek out a novel object to be its referent. As noted in Chapter 1, this type of novelty bias allows children to successfully complete referent selection tasks, which can underpin successful fast mapping. Referring back to Markman's Mutual Exclusivity Principle, we can see there are many similarities, but one primary difference. Mutual Exclusivity also claims that young children assume that an object can only have one name. The Mutual Exclusivity principle proposes that children will map a novel label to a previously unknown and unlabelled object, as they will actively *avoid* attaching a second label to the already familiar object. Thus the Mutual Exclusivity Principle suggests an active evasion of familiar objects. Although the outcome is the same (novel label attaches to novel object) the N_3C principle posits an active preference for *un*familiar objects, rather than an avoidance of familiar ones.

A further explanation has since been suggested to explain why we attach a novel label to an unfamiliar object that reflects pragmatic, social cues (Diesendruck & Markson, 2001). When children are faced with a comb and a novel artefact, if the experimenter asks for the ‘dax’ the children reason, ‘If you had meant for me to give you the comb, you would have asked for the comb, as you did not, I must assume you are referring to the unfamiliar artefact'. Here I make no claims about which theory offers the best explanation of the observed behaviour (i.e., selecting a novel artefact in response to a novel name). I merely point out that this simple phenomenon is commonplace and can be explained in a variety of different ways. Also, if the observation that this phenomenon extends beyond words (to artefact actions) it would provide evidence that domain-specific theories should be abandoned.

The final, potentially important principle from Golinkoff et al.'s (1994) proposal is labelled 'categorical scope' (also called 'taxonomic bias'). Relevant when discussing artefact information for use (name, action and function) as categorical features of an artefact, this principle suggests that children will extend a novel artefact name to other artefacts they deem to belong to the same category. Children seem able to categorise artefacts using a number of different features including shape and function (which we will return to in Chapter 4). The important point here is that children will rapidly categorise artefacts using appropriate kinds of novel information: it simply needs to be established whether action and function appropriate kinds of information when categorising artefacts.

2.1.2 Fast Mapping and Domain Specificity

There are a number of studies that have aimed to replicate and further investigate Carey and Bartlett's (1978) original fast mapping methodology (e.g., Horst & Samuelson, 2008; Vlach & Sandhofer, 2012). Carey & Bartlett's methodology was specifically designed to investigate real-world word learning in a controlled environment. In traditional fast mapping studies, children inferred a novel word-artefact mapping in a referent selection task. To successfully complete any of these tasks, we can speculate that a number of the aforementioned learning principles were in place. Domain-specific theorists propose that these principles are unique to word learning. Moreover, that it is these domain-specific processes, which make us such proficient word learners at such a young age. To be such skilled word learners, researchers suggest that something specific to language acquisition must be driving learning (Hauser, Chomsky & Fitch, 2002). If fast mapping were specific to word learning, then it follows it would only be used for learning novel words.

Aiming to investigate whether these principles were specific to word learning, Waxman and Booth (2000) studied the extension of artefact names and linguistically presented facts. Although children were required to map the novel information in a rapid learning environment, and children were tested after a delay period, exposure was explicit. As such, although often cited as a fast mapping study, this methodology does not meet my criteria outlined in Chapter 1 for a stringent fast mapping procedure (incidental learning, minimal exposure, and long term retention).

Children were shown 10 artefacts (four familiar and six unfamiliar), one at a time, and exposed to a novel name-artefact mapping or a novel fact-artefact mapping. The target artefact was either labelled "It is called a Koba" or the children were told a fact "My uncle gave this to me". Children were tested on the extension of this information either immediately or one week later. They were then shown the target and a 12 new items (two novel exemplars of each of the unfamiliar items seen during exposure). Children extended the novel names to the novel exemplars in the word condition, but did not extend the novel facts in the fact condition.

In their discussion, Waxman and Booth argued that the results suggest that different learning mechanisms are used when learning words than when learning facts. They hypothesise that children in the word learning condition rely on a dedicated, domain-specific word learning mechanism allowing them to categorise and extend the novel name; this mechanism is not engaged when learning novel facts. They further proposed that arguments against domain-specificity hypothesis were "premature" (Waxman & Booth, 2000).

However, there is growing body of research that suggests word learning may *not* be as domain specific as initially believed. The principle criticism of Waxman and Booth's (2000) conclusions is that facts like 'my uncle gave me this' are obviously not extendable (Bloom & Markson, 2001). A number of researchers argue against a domain-specific mechanism and propose that it is just one example of a more domain-general phenomenon (e.g., Bloom & Markson, 2001; Childers & Tomasello, 2003). Another approach suggests that, at least the referent selection component of fast mapping relies on an understanding of social cues (Diesendruck & Markson, 2001; Grassmann, Stracke & Tomasello, 2009).

2.1.3 Domain General Approach to Fast Mapping

Childers and Tomasello (2003) aimed to investigate extension of artefact information as a direct comparison to Waxman and Booth (2000). Highlighting the criticism that the facts used were not logically extendable to other within-category members, Childers and Tomasello discuss non-linguistic behaviours that might be expected to extend in a manner similar to words, and chose to compare artefact name and artefact action learning. They suggest that children typically learn how to use novel artefacts by watching adults interact with them. They proposed that should children extend both the novel words and novel actions in the same way, this would suggest that word learning is part of greater, more domain-general learning mechanism. This is exactly what they found, following the training methodology (and even using the same artefacts) as Waxman and Booth (2000), their results indicated that $2^1/_2$-year-old children extend artefact actions as readily as names.

More recently, and also in contrast to Waxman and Booth's analysis, Deák and Toney (2013) obtained evidence consistent with word learning tapping domain general processes. In their research, once again following a similar methodology, they claim that children *were* able to fast map novel words, facts and pictograms. Moreover, they successfully extended this information to novel exemplars of the same category. Although the authors claim fast mapping results, once again this methodology did not meet the fast mapping criteria, as exposure was focused and explicit.

In a series of three experiments, children were taught four artefact-name mappings, artefact-fact mappings or artefact-pictogram mappings during an exposure to a series of 13 familiar and four novel items. The children were tested on comprehension, production and generalisation (extension). They found that children retained facts containing novel words (e.g. this came from Saybu) faster than the words themselves (e.g. this is a Saybu). Also 3- and 4-year-old children extended novel names, facts and pictograms equally. They hypothesise that rather than the word learning processes, it is the developing lexicon itself that is unique, because of how large and complex it gets. They conclude that fast mapping is a general learning process and indeed word learning is part of a greater general learning mechanism.

As noted in Chapter 1, none of these studies meet my definition for fast mapping (brief exposure, no explicit teaching, leads to a long lasting memory). Deák and Toney (2013) describe fast mapping as 'one trial learning'. Although children were given very brief training, it was explicit – children were explicitly told that they would learn about some new objects and they should try to remember what they learn. Childers and Tomasello (2003) were a little less explicit, the children were not told that they were learning anything or to try to remember it but (as with Waxman and Booths original study), it lacked the implicit nature of the referent selection task. All items, familiar and unfamiliar, were introduced with equal vigour, for example, "Look at this, this one is so special to me. And you know what? It's called a koba". In this way naming was absolutely explicit, rather than being introduced implicitly through lexical contrast (e.g., "…bring me the koba, not the comb, the koba…).

A further limitation is that children were only tested in an immediate condition: so no long term retention was demonstrated. Childers and Tomasello (2003) only tested children immediately after the training session. Only Deák and Toney's (2013) third experiment introduced a one-week delay (and then without extension). Moreover, children were tested immediately after training (with feedback) and again a week later. One could argue that feedback actually provided a further exposure session.

While the previous research provides evidence consistent with the fast mapping of artefact actions, it does not demonstrate it. In my first three experiments I sought to demonstrate that actions could be fast mapped. In Experiment 1, I undertook an investigation into whether young children use a novel action to referently select a novel artefact. Children were not told that the action demonstrated by the experimenter was the action related to the artefact's use. Experiment 2, went on to examine whether after a brief exposure, children can retain and extend this information: that is whether actions could be fast mapped. Experiment 3 investigated whether children had simply remembered that *a novel action* had been performed on the novel artefact, or whether they retained the *specific* novel action performed by the experimenter. Should the word learning principles outlined above be the product of more general learning process, then the artefact actions demonstrated in these experiments could be fast mapped. If however these principles are specific to word learning, then I should find no evidence for the fast mapping of actions.

2.2 Experiment 1: Do Children Use a Novel Action to Select a Novel Artefact?

2.2.1 Introduction

The potential principles needed to successfully complete such a task (for example novel referent selection or mutual exclusivity bias) are widely discussed within the language literature (Markman, 1990; Mervis & Bertrand 1993; Golinkoff, Mervis & Hirsh-Pasek 1994). No one has previously tested whether or not children display the same propensity to use a novel action to select a novel artefact as they do with novel words. This was the simple premise behind the first experiment: when presented with a familiar artefact and novel artefact, which would children select as the referent of a novel action?

Experiment 1 used a simple design. I chose an artefact whose familiarity has been established from parental report in a previous study – a door key (Holland, 2014). This artefact also has the advantage of being associated with a highly distinct action (a rotation of the wrist). The unfamiliar artefact was a four-way radiator key of similar size (also used in later research, displayed in Table 3.1). Both artefacts had similar physical properties, and both afforded the same action while have distinctively different shapes. Children were allocated to either a novel word or novel action condition. In the novel word condition, the experimenter asked children to "…pass the koba". I predicted that they would select the unfamiliar radiator key. If children behaved in the same way with novel actions as novel words, then they would also choose the radiator key when asked to, "…pass me the one we do this with [pantomiming a novel action]." If however, children do not follow the same referent selection principle with actions as they do for words, then children should show no preference for the novel item.

2.2.2 Method

Participants

Data were collected from 90 reception-aged children (4- and 5-year-olds) with a mean age of 4 years 10 months. For more detailed participant information breakdown please see Table 2.1. All the children attended primary schools in a Greater London Borough. Head teachers and class teachers gave initial consent and parents were given the opportunity to opt out of the study.

Table 2.1: Experiment 1 – Breakdown of Age and Gender of Participants.

Measure	Novel Word	Novel Action
n	45	45
Mean Age (years; months)	4; 10	4; 10
Age Range (years; months)	4; 6 – 5; 6	4; 6 – 5; 6
Gender (M/F)	17 / 28	23 / 22

Design

This experiment used a between participants design. The children were unsystematically allocated to two groups testing the conditions of the independent variable: Information Type (Novel Word / Novel Action). The dependent variable was selection accuracy - selecting the novel artefact.

Materials

Two artefacts were used during the experiment, one familiar to children (a door key) and one unfamiliar (a 4-way radiator key) the ‘koba’. Each participant required one piece of blank paper and some colouring pencils for use during the drawing game.

Procedure

All the children were invited to play a drawing game with the experimenter, one at a time, and tested individually, in a quiet corner in their classroom at school. The experimenter sat at the table with some blank paper, a set of colouring pencils and the two artefacts, placed on the table close by to the child and the game. The child was initially asked to pick their favourite colour colouring pencil from the selection provided. The first and introductory task asked the children to draw around their own hand and then draw around the experimenter's hand. The paper was then turned over. The experimenter then asked the child one of two questions depending on the condition. Either "Please can you pass me the koba for us to draw around?" in the novel word condition; or "Please can you pass me the object we do this with to draw around?", whilst demonstrating a pantomimed action of rubbing their hand against the upper arm. This action was clearly different from the familiar action associated with a door key (wrist rotation with the hand oriented away from the body). Whichever artefact the children select was then used as a drawing template. This also served as a record of the selected artefact.

2.2.3 Results and Discussion

As you can see from the Table 2.2, the majority of participants selected the novel artefact in both naming and action conditions. As there were only two items to choose from, children had a 50% chance of selecting the unfamiliar artefact. Binomial distribution calculations indicate that participants in both conditions selected the novel artefact significantly more often than chance ($p < .001$). Furthermore, Chi-squared analyses revealed no significant difference was found between the two conditions (χ^2 (1) = 2.736, $p = .098$).

These data suggest that children are equally likely to use a novel action to select a novel artefact as they do with novel words.

Table 2.2: Experiment 1 – Number of Children Selecting the Novel or Familiar Artefact.

	Condition			
	Name		Action	
	n (of 45)	%	n (of 45)	%
Novel Artefact	40*	88.9%	34*	75.6%
Familiar Artefact	5	11.1%	11	24.4%

*exact binomial *p* (one-tailed) < .001

These data suggest that children treat novel actions in the same way that they treat novel words: that is novel actions should be associated with novel artefacts. These data were submitted for publication in an article that went on to become Riggs, Mather, Hyde and Simpson (2015). These data do not appear in the final version of this paper. A reviewer of the original article pointed out that our methodology did not demonstrate that children associated novel actions with novel artefacts. It merely demonstrated that children have a preference for novel artefacts. This limitation was addressed using data collected by another researcher, and so those data do not appear in my thesis. However, I return to the question of whether children associated novel information with novel artefacts in Chapter 4.

Despite the methodological concern, these data do support the proposal that children have a novelty bias – that is they tend to select novel items. There is evidence for this in the word learning studies of Mather and Plunkett (2012) and Horst, Samuelson, Kucker and Murray (2011). In both these studies, children completing a novel referent selection task were given the choice between a previously seen, but un-named novel artefact, and a new 'supernovel' artefact. Two-year-olds chose the supernovel artefact when hearing a novel name, despite also not knowing the name for the previously-seen novel artefact. It would appear that although there was no logical reason to exclude the previously-seen novel artefact as a target, this is exactly what children do: favour the *most* novel item. As with my data above, it doesn't tell us what processes are at work in word (or action) learning, simply that children have a preference for novelty. Could this broader preference for novelty undermine claims about the specificity of word learning principles? This next experiment aimed to test this proposal further.

2.3 Experiment 2: Investigating Fast Mapping and Extension of Artefact Names and Actions

2.3.1 Introduction

Data from Experiment 1 suggest that children may use the principles of mutual exclusivity to pass a referent selection task, which maps a novel action onto a novel artefact. Confident that children are capable of this kind of referent selection, I wished to test whether they are able to fast map and thus retain the novel artefact action over a longer period of time. As mentioned previously, there have been a limited number of studies that begin to investigate fast mapping of non-lexical information (Deák & Toney, 2013; Childers & Tomasello, 2002 & 2003; Campbell & Namy, 2003).

Original fast mapping research (which does meet strict fast mapping criteria- brief exposure, no explicit teaching, leads to a long lasting memory) suggests children also fast map novel facts (Markson & Bloom, 1997). However <u>*none*</u> of these studies since, which are often cited as fast mapping, meet the original criteria (Carey & Bartlett, 1978 Markson & Bloom, 1997), which I have adopted here. This further research suggests children may also map novel facts using both familiar language and also facts containing a novel word (Deák & Toney, 2013). It has also been established that children map novel verbs to novel actions (Merriman, Marazita & Jarvis, 1995; Merriman, Evey-Burkey, Marazita & Jarvis, 1996). With regards to non-verbal information, Deák and Toney (2013) also found that children were able to map pictograms, and other research proposes evidence of children's fast mapping of actions or melodic sequences (Childers & Tomasello, 2002 & 2003; Campbell & Namy, 2003 respectively).

The design of my second experiment endeavoured to further the work of Childers and Tomasello (2002, 2003) and Hahn and Gershkoff-Stowe (2010) using a strict fast mapping methodology, as originally designed by Carey and Bartlett (1978). Childers & Tomasello, (2002) describe the learning of artefact action as perhaps the most natural non-verbal learning that young children will engage in. Once again, I wanted to directly compare the action learning to word learning. Neither the Childers and Tomasello (2002 & 2003) nor the Hahn & Gershkoff-Stowe (2010) were specifically designed to be fast mapping studies, although they are often cited as such due to the relatively brief exposure of the novel information.

However, both the Childers and Tomasello (2002, 2003) and Hahn and Gershkoff-Stowe (2010) were designed to investigate whether it was *possible* to retain and extend artefact-actions. In consequence it was appropriate for them to use very explicit teaching of the novel information: for example, "This is called a booma, see the booma? Can you say booma?" (Hahn and Gershkoff-Stowe, 2010). Thus their methodologies clearly differ from Carey and Bartlett (1978) in which the novel name is only presented 'in passing' as part of an interaction which is not about the explicit teaching of anything.

Secondly, and of equal importance, are the amount of exposure and delay in testing. In the Childers and Tomasello (2002), children were exposed to the novel information repeatedly over a series of days. This means that although the children were required to retain the information over a significant period of time (e.g., 7 days), they were also given the opportunity to re-establish the original mapping. In Childers and Tomasello (2003) and the Hahn and Gershkoff-Stowe (2010), children were only given one brief exposure to the novel information. However, they were not required to retain and recall this information after a significant delay: thus not demonstrating long-term learning. I needed to incorporate *both* factors simultaneously: children were only exposed to the novel information in a single exposure session, *and* were required to retain and recall this information for six - seven days (without further training).

Another precaution taken in this experiment was to ensure that the artefacts did not afford their actions and that the action was 'effectless'. For real-world artefacts, the physical shape of an artefact can give clues to its action and functional capabilities and the action that should be made to achieve them (Michaels, 2003; Symes Ellis & Ticker, 2007). For example, shears afford holding the object by their handles, and opening and shutting the blades about the pivot. Even if you had never seen shears you might be able to work out what action to make with them. As in both the Childers and Tomasello articles (2002, 2003) and Hahn and Gershkoff-Stowe (2010) it was important to establish that the children could <u>not</u> *infer the action* from the shape of the artefact. Hahn and Gershkoff-Stowe (2010) are careful to highlight the arbitrary nature of the actions performed, ensuring they were not related to the object's structure as "actions related to an object's form could be inferred through an object's structure or parts rather than retrieved from memory" (Hahn & Gershkoff-Stowe, 2010; p.288).

Likewise I wished to ensure that children could not infer the action by recalling the target artefact's function. If children saw the target artefact achieve its function, they could use this information to infer the action that should be made with that artefact (even if they have not remembered it). For example, inferring a hammering action by remembering that an artefact's function is to 'break things'. As the action on the target artefact caused no obvious effect (i.e., produced no inferable function), children needed to recall the action rather than rely on inferring it from the function.

Finally, this experiment aimed to test whether children will extend novel artefact actions in the same way as novel artefact names (i.e., to new exemplars of the same shape but different size and colour). The categorical scope principle (Golinkoff, Mervis & Hirsh-Pasek, 1994) suggests that children understand that a novel artefact's name will also apply to other exemplars from the same category. An artefact's action can arguably be described as a feature that is consistent across all members of an artefact category. This certainly reflects our everyday experience – where the same action is usually appropriate for all members of an artefact category. Childers and Tomasello (2003) found that, when tested immediately after exposure, children would extend novel actions in the same way as novel names. They suggest that children will extend all artefact information that is deemed a characteristic feature of its category. Therefore, if the categorical scope principle is applicable to non-lexical features, as Childers and Tomasello (2003) suggest, then children should readily select within-category exemplar in my delayed extension test of artefact.

2.3.2 Method

Participants

This study (and all those following) recruited new children who had not been previously tested. In this study, participants were slightly younger than Experiment 1 to see if a mutually exclusive understanding of action was also demonstrated at a younger age. Data were collected from 78 children aged 3 to 4-years-old (38 girls and 40 boys with a mean age 3 years, 11 months). The children attended nursery schools in outer London (see Table 2.3 for a more detailed breakdown).

Table 2.3: Experiment 2 – Breakdown of Age and Gender of Participants.

Measure	Novel Naming	Novel Action
N	39	39
Mean (years; months)	3; 10	3; 11
Range (year; months)	3; 3 - 4; 11	3; 2 - 4; 11
Gender (M/F)	13/16	10/19

Design

Using a between participants design children were unsystematically allocated to one of two conditions testing the independent variable: Information Type (Novel Word or Novel Action). The dependent variable was comprehension selection accuracy after a five to seven day delay (e.g., whether children selected of the original target artefact at test).

Materials

In total, the procedure required 10 artefacts, five during the exposure session and five during testing. Following the procedures of Bloom and Markson (1997), Waxman and Booth (2000) and Childers and Tomasello (2003), there was a mixture of familiar and novel items. During the exposure session the two familiar artefacts were a green felt pen and a red pencil sharpener. The three novel artefacts were a white 'T' shaped plastic plumbing fitting, an orange 'L' shaped plastic bracket, and a black staple remover.

The use of each item as the target artefact was counterbalanced across participants. The artefacts used in the testing session were the same shape, but varied from the originals seen in exposure in both colour and size. During the testing session, artefacts included: an orange felt pen and green pencil sharpener and a smaller black plumbing fitting, a larger white L shaped bracket, and a larger red staple remover. Care was taken to ensure that none of the artefacts afforded the novel action.

Procedure

Each child was asked to play a game with the Experimenter (E), individually, in a quiet corridor of the school. E sat across the table from the child and placed a piece of paper displaying the outline drawings of the five test artefacts. E emptied the artefacts from a brown bag onto the table and asked the child to play a matching game, matching the artefacts with their pictures. Although most children found this task easy, help was given if required. Once the artefacts had been successfully 'matched' E told the child that they were going to put each of the toys away into either the red or blue bag. One by one E pointed to an artefact and instructed the child to hand it across the table. The child was allowed to pick which bag the artefact went into (red or blue), and E placed it inside. E followed this procedure for the five artefacts in the following order: novel artefact, familiar artefact, novel target artefact, familiar artefact, novel artefact. When collecting the third, target, artefact each child was exposed to novel information (differing depending on their condition allocation).

In the novel word condition, E pointed to the novel target artefact and asked the child to pass them the 'koba'. When E received the artefact the child was asked which bag the koba should go into. The artefact was placed into the bag the child selected. In the novel action condition E once again pointed to the novel target artefact and asked the child to pass them the artefact "we do this with" (whilst pantomiming the action of rubbing her right hand on her left upper arm). Similarly when given the artefact, E asked into which bag she should place "the one we do this with" (this time demonstrating the same action, but with the artefact in her hand). In both conditions the children were exposed to two demonstrations of the novel information. In neither condition were the children explicitly told the new information for example, "This is a koba, we use it as an arm-scratcher like this [demonstration]." Neither were the children instructed to try and remember the information for later. Once all the artefacts were packed away the children were allowed to return to the nursery.

The test session took place five to seven days later. E repeated the matching game again, this time with the aforementioned five novel test artefacts (same shape, different size and colour). After all the artefacts had been successfully 'matched' and placed on the paper, E asked either "Can you point to the koba?" for children in the novel word condition, or "Can you point to the one we do this with" (pantomiming action of rubbing upper arm) for the children in the novel action condition. Children were then thanked for their help with the game and shown back to the nursery.

2.3.3 Results and Discussion

When tested five to seven days after initial exposure, the majority of children correctly choose the target artefact from those on display. The results were very similar across both conditions: 66.7% in the Novel Word condition and 61.5% in the Novel Action condition at levels significantly above chance (Table 2.5). Overall, children selected the correct target artefact at a rate significantly above chance performance. This is true both if children had assumed all five artefacts were suitable novel referents for attaching their novel information (20%, binomial $p<.001$), or if they assumed only the novel artefacts were possible referents (33%, binomial, $p<.001$). There was no significant difference between the accuracy results of the two conditions (odds ratio = 1.25, $p = .64$). These data suggest that children *are* able to rapidly and enduringly map novel action information onto a novel artefact. Furthermore, they were as successful at achieving this with artefact actions as artefact names (an ability often proposed for children of this age).

When examining this in greater detail we can see exactly what they have achieved. Three- to 4-years-olds observed only two incidental demonstrations of a novel action (or word) during one brief exposure session, where learning was not the primary objective of the interaction with the experimenter. After a five to seven day interval, children were able to successfully recall which artefact related to the novel information presented (either its name or action). Moreover, not only were they able to retain and recall this information for successful use a week after exposure, they also managed to further use this knowledge to extend it to another novel exemplar of the artefact category (based on shape). This has also previously been seen for children learning novel artefact names (Waxman & Booth, 2000).

Arguably, although the above data implies that this is the case, it could be reasoned that perhaps the demonstration of the action (or name) alone stood out from the rest of the procedure. Perhaps children hadn't recalled that a specific action was performed on the target artefact, merely that *something* was done with this specific artefact. If the children were shown a different action at test would they continue to select the target artefact as the one that was acted upon during exposure?

2.4 Experiment 3: Examining the Specificity of Action Fast Mapping

2.4.1 Introduction

As an extension of Experiment 2 it was felt necessary to clarify whether or not the children had in fact formed a real mapping in the novel action condition, and if so, what specifically they had mapped. If the children had merely recalled which artefact had been acted upon, this would not require any long-term artefact-action mapping, simply the ability to recall which one item had been 'singled out' during the first matching game. Additionally, if an action has been mapped, have the children retained the specific action initially used when demonstrated upon said artefact or simply a 'strange action'?

I sought to overcome this limitation of Experiment 2 by further comparing performance on two action conditions which only differed at test. I compared performance on a novel action condition (as before) to a second novel action condition in which a different novel action was performed during the testing session. The reasoning was that if children had simply recognised that a 'strange action' had been performed on the artefact, but not mapped the action specifics (rubbing up and down the upper arm), then they would continue to select the target artefact even when a new novel action was performed at test. However, if children had successfully mapped the specific action to the target artefact then they would not consider the original target artefact was a referent for the new novel action. I proposed that under these circumstances children would instead pick one of the alternative novel artefacts due to mutual exclusivity (or whatever bias caused children to select a novel artefact in Experiment 1).

2.4.2 Method

Participants

Data were collected from 60 3- and 4-year-old children (29 girls & 31 boys; mean age 3 years, 10 months). All the children had not been previously tested and attended a nursery in Greater London. The children were unsystematically allocated to half in each experimental condition (Table 2.4).

Table 2.4: Experiment 3 – Breakdown of Age and Gender of Participants.

Measure	Novel Action	Second Novel Action
n	30	30
Mean (years; months)	3; 10	3;10
Range (year; months)	3; 4 – 4; 6	3; 3 – 4; 6
Gender (M/F)	17/13	14/16

Design and Materials

The design followed that of Experiment 2, with the two experimental conditions being novel action or second novel action. The materials used were the same initial five artefacts used in the exposure session of the previous experiment.

Procedure

The exposure session was identical to the novel action condition outlined in Experiment 2. The Experimenter once again demonstrated the action of rubbing her right hand on her left upper arm. In the testing session the two familiar and three novel artefacts were placed on the table between the Experimenter and the child. This time children in both conditions were asked to 'point to the one we do this with' but the experimenter changed the action for children participating in the second novel action condition. For children in the novel action condition E performed the same action as used at exposure; for children in the second novel action condition E performed a circular motion on the table (a previously unseen action). This second test action was different from the initial exposure action, both in how it was performed (linear motion vs. circular motion) and the substrate it acted upon (arm vs. table).

2.4.3 Results and Discussion

In the novel action condition performance was similarly successful to that reported in Experiment 2 (see Table 2.5) with the majority of children (24/30, 80%) selecting the correct target artefact: binomial distribution calculation, $p<.001$ (with chance at 1/3). In the second novel action condition, just 16.7% (5/30) of the children selected the original target artefact; significantly less than predicted by chance (binomial, $p=.020$). Nearly all the remaining children selected one of the other unfamiliar artefacts (23/30, 76.7%). The final two children selected one of the familiar items (6.6%).

Table 2.5: Experiment 2 and 3 – Percentage of Children Selecting the Target Artefact.

Selection	Experiment 2		Experiment 3	
	Name Extension	Action Extension	Novel Action	Second Novel Action
Target Artefact	66.7%*	61.5%*	80.0%*	16.6%

*exact binomial *p* (one-tailed) < .001

These results, following Experiment 2, strengthen the proposal that young children are able to successfully retain, recall and extend a novel artefact–action mapping; rather than just demonstrating a more general target preference. Moreover, as children didn't continue to select the original target artefact in the second novel action condition, it would suggest that children are more than merely remembering a 'strange action' performed on the target, but retaining an accurate sensorimotor representation of the novel action. Additionally, these results further support the findings from Experiment 1, that children will attend to a novel action in the same way they will a novel word, by excluding referents for that novel action for which they have already know an action. The majority of children shown a second novel action would did not select the target artefact, as even after their initial brief exposure it was understood that the first novel action was the specific action associated with the target artefact. Therefore a second novel action must belong to one of the other *novel* artefacts.

2.5 General Discussion

The results from these three experiments suggest that children can rapidly and enduringly learn actions associated with artefacts. This is an exciting first step towards understanding the learning of artefact knowledge for use. In these experiments, I directly compared children's novel word and action learning, and the results proved similar throughout.

Experiment 1 provided initial evidence that young children have the ability to correctly perform a novel referent selection task for both novel artefact actions and names. However, only testing children using a novel condition did not address the alterative explanation that children simply have a general novelty bias (Mather & Plunkett, 2010, 2012). My experiment was followed-up to address this methodological concern. A new group of 61 participants were tested over four trials using four familiar and four novel artefacts (these data are presented in Riggs, Mather, Hyde & Simpson, 2015). The children were once again allocated to either the action or word condition; however, in this experiment children's responses to familiar actions and words were also examined. In two trials children were asked to select an artefact on seeing a relevant familiar action/name, and in two trials they were exposed to a novel action/name.

Children chose novel artefacts when presented with novel information (76.7% novel words; 70.9% novel actions; binomial, $p < .001$); and familiar artefacts when presented with familiar information (86.7% familiar words; 80.6% familiar actions; binomial, $p < .001$). To be clear, in familiar trials, children selected the familiar artefact associated with that familiar action (e.g., a brush making a hair brushing action). These results allow us to discount a simple novelty bias, because children did not continue to select the novel artefact when a familiar action was demonstrated. I investigate referent selection further in Chapter Four.

Following the results of both of my Experiment 1 and those presented in Riggs et al. (2015), it seems justified to suggest that children do use similar learning principles when faced with a novel artefact action as a novel artefact name. That is, when faced with novel action and names children tend to associate them with novel artefacts. It may also be the case that, under the right condition, children have a more general attentional bias towards novel stimuli (Mather & Plunkett, 2012) or even away from the familiar (McMurray, Horst & Samuelson, 2013). Whatever the precise mechanism, based on the current data I propose that a domain general process is used to map both words and actions.

In the second experiment, children retained and recalled artefact names and actions, gleaned from a minimal exposure, after a week later. Once again there was no significant difference between the novel word and novel action conditions. Moreover, children were able (after a week's retention) to extend this new information onto novel exemplars from the same artefact category. Finally, from Experiment 3, I obtained evidence for the fidelity of children's artefact action learning. Children did not simply remember that *a novel* action had been performed on the novel artefact (with no care as to what that action was). When faced with a new novel action at test (different from the novel action used in the exposure session), they did not select the target artefact. Instead, having remembered the original novel artefact action mapping, children seemed to assume that this new novel action must be associated with one of the other novel artefacts.

Overall the data from these three experiments clearly add to the literature. These data support and extend those obtained by Childers and Tomasello (2002; 2003) and Hahn and Gershkoff-Stowe (2010) suggesting that children are able to learn novel artefact action mapping as readily as they learn novel artefact names. In particular my data demonstrate that children can fast map artefact actions – using Carey and Bartlett's (1978) original, stringent criteria (incidental learning, minimal exposure, and long term retention).

Children have exhibited similar learning behaviour, under identical exposure conditions, for novel artefact actions and novel artefact names. It appears as if they can potentially learn how a novel artefact is manipulated (its action) in the same way they learn what it is called. These findings certainly support the view that word learning does not rely on specific word learning processes (Markson & Bloom, 1997; Bloom, 2000; Bloom & Markson, 2001; Childers & Tomasello, 2003; Deák & Toney, 2013). Furthermore, it would suggest that proposed domain specific word learning principles (e.g., mutual exclusivity and categorical scope – Markman, 1990; Golinkoff, Mervis & Hirsh-Pasek, 1994) required to perform referent selection tasks and category extension are not in fact restricted to word learning. Instead, whatever these principles are and however they operate, they do not seem to be restricted to words.

Moreover, fast mapping does not appear unique to word learning. With these experiments following a stricter fast mapping methodology than most preceding studies (Childers & Tomasello, 2002, 2003; Hahn & Gershkoff-Stowe, 2010), I have more convincingly demonstrated that fast mapping is a domain-general process (or at least not a uniquely lexical process). That being said, it is also likely that children do not fast map everything. In Riggs, Mather Hyde and Simpson (2015), we include a fourth experiment (again, not presented here, as I did not collect the data). In this experiment we test whether visual facts are fast mapped. This is a replication of Markson and Bloom's (1997) visual fact condition in which a sticker is attached to the target artefact. We report that in the novel action condition children once again successfully recalled the target artefact after a week's delay (69% correct); however in the visual fact condition, they were not able to recall which artefact the sticker was attached to (23% correct – no better than chance). Thus these data support Markson and Bloom's (1997) proposal that not all information is fast mapped.

I have suggested that the novel action made with the target artefact in my experiments (e.g., rubbing on the experimenter's arm) was 'effectless'. In the real world we rarely, if ever, see actions made on artefacts that are effectless. Despite this, children remembered the novel action in my experiments. The ability to remember effectless actions is consistent with imitation research, in which children are good at learning actions that have no obvious purpose (e.g., White, McGuigan, Marshall-Pescini & Hopper, 2009; see section 1.4.1). Nevertheless, on reflection we think that it is not absolutely certain that children inferred no function in my experiments. They could, for example, have inferred that the target artefact's function was as an arm scratcher. Thus we cannot be absolutely certain that children are remembering simply the novel action in my experiments, rather than remembering a function and merely inferring the action. With this in mind we aimed to improve our methodology in the next chapter.

The Next Chapter

The next chapter investigates the learning of function knowledge using strict fast mapping criteria (incidental learning, minimal exposure and long term retention). Experiment 4 directly compares comprehension of name, action and function information following demonstrations of a novel artefact in use. Experiments 5 and 6 examine the effect of labelling and reduced exposure on comprehension. Experiment 7 investigates production of artefact name & action following fast mapping exposure.

Chapter Three

Children Fast Map Artefact Functions as Efficiently as Artefact Names, but Artefact Actions are Learnt Most Easily

Some of the methods and data that appear in this chapter have been published in Holland, A., Hyde, G., Riggs, K. J., & Simpson, A. (in preparation). Young children learn the actions associated with artefacts more easily than they learn their functions and names.

3.1 Introduction

Results from the previous chapter suggest that children are excellent learners of artefact actions. They successfully select a novel referent based on its action. Furthermore, children can retain novel action-artefact mappings for a week, and extend this mapping to novel within-category exemplars. This coupled with previous research (Childers & Tomasello, 2002, 2003; Hahn & Gershkoff-Stowe, 2010) suggests that children have the ability to rapidly and enduringly learn the action information needed for artefact use. My next research question is, 'Can children fast map artefact function, and how does this ability compare to their learning of names and actions?

An artefact name is spoken aloud and its action is visually observed. Both are directly perceptible: this must benefit the learning of these types of artefact information for use. Artefact function is usually the outcome of a specific action on a substrate, which brings about a change in that substrate (e.g., a bread knife acting upon a loaf of bread, changes bread from loaf to slices). Functions are not therefore directly perceptible, they must be *inferred*. Children must compare the state of the substrate before and after the artefact's required action has been performed with the artefact, in order to determine the substrate change. A proper, adult-like, *causal* understanding requires that the role of the artefact and action in bringing about that change, is inferred.

Carey and Bartlett (1978), who first investigated the fast mapping of words, suggested that incidental learning occurred when children did not think that they were engaging in formal learning. Is an artefact's function information harder to learn incidentally, due to its more conceptual nature, and the amount of information that must be integrated to understand it? Are children able to fast map function as something distinct from action?

Children could understand function as something that you do, rather than understanding it as a substrate change distinct from action. From here I will review previous research in this area, before detailing the design of my own methodology.

3.1.1 Detailed Review of Casler and Kelemen (2005) Investigation of Function learning

Previous research suggests that children are effective learners of function information. Casler and Kelemen's (2005) data suggest that children as young as two years of age can rapidly learn artefact function. In the first of two experiments in this article, 4- and 5-year-olds (and adults) were familiarised with two novel artefacts (the target and a foil). Participants' exposure to each novel artefact was kept to one minute. One had its function demonstrated, launching a foam toy from a tube, whilst the other was slotted into a similar tubular container for storage, and the participants were told a novel fact about it. The functional part of the target artefact was the same shape as the foil, and both could be used to perform the functional action (e.g., be inserted into the tube to launch the toy). Thus, although only one of the artefacts had its function demonstrated, they were both physically capable of being used to achieve this function (i.e., they both afforded it).

Immediately following this, the participants were asked eight questions in a fixed order to test their commitment to the artefact-function mapping. There was a basic recall and two extension questions. Participants were asked to choose which artefact they would need to achieve the demonstrated function (make the toy go flying): once with the original artefacts (recall), then once with the same artefacts in a different colour (extension one), and once with the artefacts in a slightly different shape and colour (extension two). Three 'effort' questions required the participants to make an effort to get the target artefact: target was out of reach (effort one), target was in a closed container (effort two) or target was a different colour whereas alternative foil artefact was unchanged (effort three). Two 'dissociation' questions were included to see which artefact participants would choose when asked to perform a *different* function (crushing crackers). Both artefacts were equally capable of completing the new task, so these questions assessed the mutual exclusivity of the artefact-function mapping (i.e., does an artefact have a single function, in the same way that it has a single name? e.g., Markman, 1990).

Overall Casler and Kelemen report both children and adults were more likely to choose the target artefact to achieve the demonstrated function in both the extension and effort trials. Children and adults alike chose the target artefact even if it was a different colour, slightly different shape, or required more effort to select. However, although children chose the target artefact significantly less often when asked to achieve a different function, only the adults consistently chose the foil in the dissociation trials; the children did not select the foil more often than predicted by chance (i.e., half the time).

As the first study only showed moderate evidence that children apply mutual exclusivity to artefact function, a simplified version of the task (with fewer questions) was used to test younger children in the second experiment. Two-year-olds, 3-year-olds and 4-year olds were once again shown two novel artefacts. As before one of the artefacts had its function demonstrated: it was inserted into a thin slot in a box to turn on a light. The foil was not shown to have any function, but the experimenter did point out that the bottom edge of the foil matched the bottom edge of the target. The foil was placed into a holder, so the action performed on both artefacts was the same.

Following exposure, with both artefacts in front of them (or colour variants), children were then asked a series of four (rather than eight) questions: two extension questions, asking which one was needed to turn the light on (demonstrated function); and two dissociation questions, asking which one they would need to crush crackers (new function). Following a one to three day delay, the same children then completed a further four trials; again, two extension and two dissociation. One of each of these questions tested children's understanding of social convention of artefact-use, "If your teacher wanted to turn on the light which one would she need?" For the extension questions, children consistently choose the target artefact when asked to turn on the light (77% of 2-year-olds, 86% of 3-year-olds and 86% of 4-year-olds). T-tests for each group revealed that children chose the target artefact more often for the generalisation trials than the dissociation trials (all $ps < 0.001$). For the dissociation trials, both the 2-year-olds and 4-year-olds chose the foil at levels significantly above chance during (age four, $p = 0.016$; age two, $p = 0.048$); the 3-year-olds data approached significance ($p = 0.083$).

Overall, Casler and Kelemen data suggest that children as young as two years of age, understand that an artefact is 'for' a specific purpose (i.e., has a single function). Furthermore, this function can be leant in only a one-minute exposure session. This knowledge was retained after a couple of days delay, and after repeated questioning (which often promotes answer switching in young participants). Moreover, children aged two to four years appeared to view this function as an inherent property of the target artefact's category, and thus extendable to other items from the same category. Finally, when asked to achieve a different function children were more likely to use a different artefact. This suggests that mutual exclusivity is applied to artefact function. If an artefact is used for one function, then it should not be used for a different function, despite even if it affords the second function.

Casler and colleagues' research (Casler & Kelemen, 2005, Casler & Kelemen, 2007; Casler Terizyan & Greene, 2009) suggests that children are able to understand function as a normative and unchanging property of an artefact; and that once learned, children can retain this function information long term (both a key feature and a result we were keen to investigate). Despite this, there are a number of concerns with the methodology this research has used.

3.1.2 Methodological Considerations with Casler and Kelemen's (2005) Research

In order to create my own fast mapping methodology it was important to concentrate on the three key criteria: incidental learning with minimal exposure leading to long-term retention. Firstly, I will discuss the ways in which Casler and Kelemen's methodology did not meet these criteria (of course, this is not a criticism of their research – as they were not trying to follow my criteria). Secondly, I will briefly discuss a few questions concerning how they interpret their results, with a view to creating a robust methodology for my own research.

Casler and Kelemen (2005) are often cited for its rapid learning and minimal exposure approach (e.g., Birch, Vauthier & Bloom, 2008; Sommerville, Hildebrand & Crane, 2008). However, considering my fast mapping criteria, the approach taken to demonstrate the novel information to the children was very explicit. The experimenter introduced themselves to the children and then immediately proceeded to show them the new artefacts and demonstrate its function. Although, the target artefacts were not described as 'for' any particular function, children were encouraged to use it themselves. Whilst this method does provide evidence that children learn artefact function from one exposure session, it does not meet my criteria of incidental learning. Secondly, Casler and Kelemen claimed children had learned the novel function after a one to three day delay. However the same children were tested *both* immediately after the exposure session, *and* after the delay. Repeat testing may have encouraged the children to remember the target artefact-function mapping. To demonstrate long-term retention following brief exposure, a between-participants design is preferable. It is therefore questionable whether Casler and Kelemen (2005) demonstrate long-term retention.

The remaining issues concern what *exactly* children learned in Casler and Kelemen's (2005) study. Although Casler and Kelemen concluded that children learnt artefact functions, I suggest that it is difficult to be sure of this. It could be argued that children have merely learned an association between the target artefact and the substrate (the substrates were the tube and light box). Children may have simple learnt a stimulus-stimulus (artefact-substrate) association, and know nothing about the artefact's function. As the substrate was still in view during the test session, children could have used their memory of the artefact-substrate association to select the correct artefact. Alternatively, children could have been remembering the artefact action (e.g., to insert the target artefact into the tube). This would allow children to pass many of the test questions, again without having learned the function of the target artefact. Is it merely the association between the target artefact and an action on the substrate children retain? In order to be more confident that children really have learnt an artefact-function mapping the substrate needs to be removed when the test questions are asked.

As discussed in the previous chapter, the properties of artefacts and the actions and functions associated with them are causally related (e.g., Symes, Ellis and Tucker, 2007; Michaels, 2003). For example, when looking at a pair of scissors, we can see that they are designed with holes into which fingers can be inserted; the blades are sharpened and pivoted in the middle. Thus when handling a pair of scissors, even for the first time, there is very little doubt as to how you hold them. Furthermore, only one functional action can performed with them. By performing that action on a suitable substrate you demonstrate scissors' function. Thus, scissors *afford* their action and so their function.

In Casler and Kelemen's study the target artefacts shape afforded its function. Casler and Kelemen designed their foils so that they afforded the same function. They suggest that as the foil is afforded the demonstrated function, children could not use the fact that target artefacts afforded its function to help them remember the target artefact. However, simply using the targets may have drawn children's attention to this affordance more for the target artefacts than for the foils (even if implicitly so). Therefore the children may have simply remembered the affordance of the target artefact (that it has the potential to be inserted in the substrate), rather than specifically its function.

In conclusion, it is not clear that children needed to remember an artefact-function mapping in order to pass the questions used in Casler and Kelemen's study. I aimed to ensure that the only way to pass my function comprehension question in the following experiment was to remember this mapping.

3.2 Experiment 4: Investigating Fast Mapping of Artefact Information for Use

3.2.1 Introduction

My aim for this experiment was to design a methodology that allowed children to observe a novel artefact being used, whilst creating a learning experience as 'real' as possible. This needed to meet my three criteria of fast mapping (incidental learning, minimal exposure and long-term retention). It also required equal incidental exposure to its name, action and function. As an aside to a game, that participants believed to be the goal of the experimenter-participant interaction, children saw an experimenter (in response to a request made by a hand puppet) demonstrate an artefact being used. One of four novel artefacts was used to perform a specific action on a novel substrate (a music box). As the action was performed the experimenter operated a secret foot pedal to start the music playing, so that it appeared that the target artefact acting on the substrate had demonstrated its function, (turning on the music).

Regarding incidental learning and minimal exposure, to ensure that the artefact information was introduced incidentally it was embedded in a game (as in Experiment 2). This meant that the children were engaging in other tasks using the target and three foil artefacts during their time with the experimenter; and ensured that the experimenter did not interact with the target artefact much more than these foils. During their time with the experimenter, the children completed a warm-up task and a distractor task with all the artefacts, before the exposure session, and then a further distractor task.

During the warm-up task the children were asked to remove four novel artefacts from a box, one at a time, and place them on the table. Children were given time to interact with the artefacts as the experimenter recorded the participant's details. In both distractor tasks the children were asked to match the four novel artefacts individually to either black and white photos (matching shape) or coloured cards (matching colour). This ensured that children interacted with all of the artefacts equally.

Whilst working with the children the experimenter used a puppet, which served two purposes. Firstly, to ensure children were not told to attend to the artefact's use. When discussing the use of the target artefact in the exposure session, the experimenter spoke directly to the puppet. The experimenter demonstrated the artefact's use twice during the minimal exposure session, both times apparently prompted by the puppet and, demonstrated to the puppet. Secondly, the puppet also helped ensure children remained engaged with the experimenter.

With regards to long-term retention, Casler and Kelemen performed testing in a delay condition after 1 – 3 days. For many researchers examining fast-mapping or rapid learning procedures, this constitutes a 'proper' delay. In fact some fast mapping research with 2-year-olds have used delays of 24-hours (Goodman, McDonough & Brown, 1998), or just 5 to 10 minutes (Heibeck & Markman, 1987; Horst & Samuelson, 2008). To be a more stringent test of learning, I felt the delay period should be longer, in line with original fast-mapping studies (Carey & Bartlett, 1978 & Markson & Bloom, 1997). I therefore used a delay of one week. Additionally, my participants were either tested in the immediate condition or the delay condition to avoid repeat testing, which could encourage children to remember the target artefact.

I also wished to ensure that it was not possible to *infer* either the artefact action or function from any other information. If children passed the action and function comprehension questions, I could be confident that they had retained this specific information. The novel artefacts used in the experiment were: a red, plastic adhesive spreader; a yellow, metal four-way radiator key; a green, plastic, air-vent cover; and a blue plastic tumble dryer ball (See Figure 3.1). Each artefact was small enough to be held in one hand and had no features suggesting how it should be held or manipulated. Care was taken to ensure that their shape didn't afford a specific grip (e.g. handles), or action, or the function that the artefact achieved. The music box substrate was a plain white box. There were no obvious holes for speakers, or buttons, dials or switches as would normally be associated with a music-playing device. As such, it appeared as if the only way to switch it on was for the target artefact to act upon it. In reality the experimenter operated the music with a secret foot pedal in order to start the music in time with the end of the action. The specific action made by the experimenter was to 'bounce' the target artefact along the top of the box three times. Looking at either the artefacts or the substrate, one could not have inferred that this was the action required.

At test, children were required to answer one of three questions, depending on their allocated condition. In the naming condition they were asked, "Which one is the koba?"; in the action condition they were asked, "Which one do we do this with?" (pantomiming the novel action); and in the function condition they were asked, "Which one starts the music playing?" During the testing session the substrate was removed from view to avoid providing a substrate-artefact cue. As mentioned previously, by having the substrate in view when asked the function question, could support retrieval of the target artefact (i.e., I remember this thing was used with the music box). By careful selection of the novel artefacts and action, and by removing the substrate from view I aimed to ensure that children could only answer the test questions correctly by remembering the relevant information.

When deciding upon a suitable age range, I considered previous function research. There is evidence consistent with the proposal that 2- to 3-year-olds understand that function is a normative property of an artefact (Casler & Kelemen, 2005, 2007; Casler, Terziyan & Greene, 2009). Additional research indicates 3- and 4-year-olds understand that artefacts were designed by a creator with a specific label and function (Jaswal, 2006), and that 3 – 4-year-olds can understand that an artefacts structural properties are designed to achieve a function (Asher & Kemler Nelson, 2008). Even that 2-year-olds may understand that an artefact category name can be extended to novel exemplars with the same function

(Kemler Nelson, Russell, Duke & Jones, 2000). These studies suggests that children in this age range understand something about artefact function – without testing their ability to fast map an artefact-function association. This experiment tested 3- and 5-year-olds.

3.2.2 Method

Participants

All the children attended primary schools in the Greater London area. Data were collected from 144 children (69 girls), 72 3-year-olds (mean = 3,7; range 3,1 - 3,11) and 72 5-year-olds (mean = 5,2; range 5,0 - 5,6). Both head teachers and class teachers gave permission for their pupils' participation, and then parents were given the opportunity for their children to opt out of the study. (For further breakdown of participant information across conditions please see Table 3.1).

Design

This experiment used a between participants design. The independent variables were time interval (immediate / delay) and information type (name / action / function). The children were then unsystematically allocated to one of six experimental conditions (name immediate, name delay, action immediate, action delay, function immediate, function delay) to test the dependent variable, comprehension accuracy (selecting the target artefact at test).

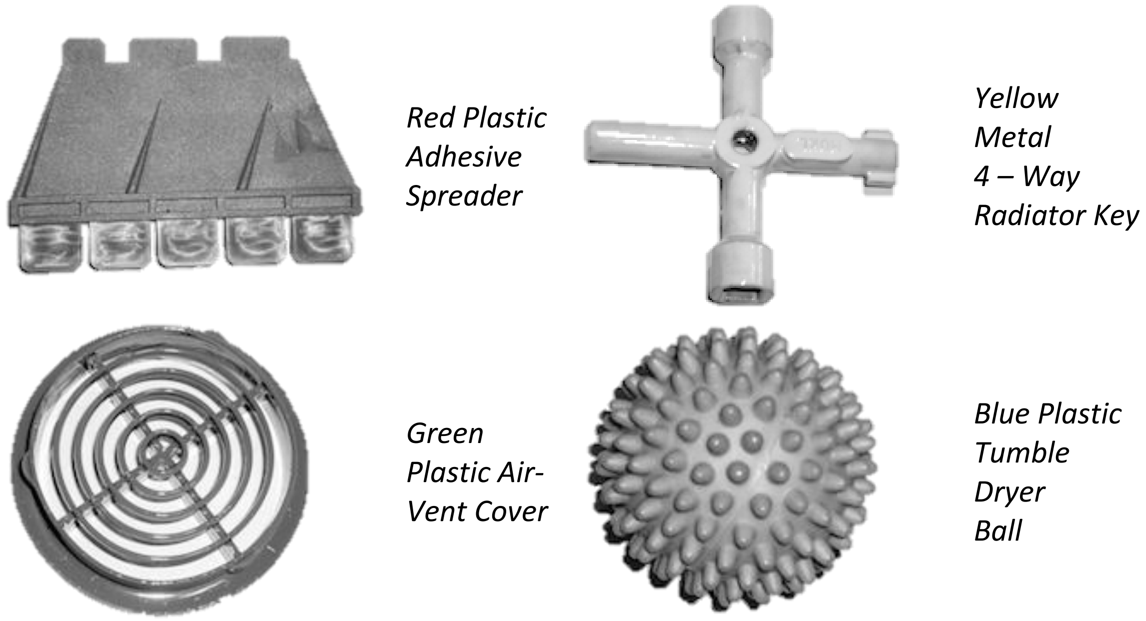
Table 3.1. Experiment 4 – Table to Show Age and Gender Breakdown Across Conditions.

Age Group	Time Delay	Measure	Name	Action	Function
3-Year Olds	Immediate	n	12	12	12
		age (yrs, months)	3, 7	3, 6	3, 8
		range (yrs, months)	3,1 – 3,11	3,1 – 3,11	3,3 – 3,11
		Gender (M/F)	9 / 3	6 / 6	5 / 7
	Delay	n	12	12	12
		age (yrs, months)	3, 7	3, 6	3, 8
		range (yrs, months)	3,1 – 3,11	3,3 – 3,11	3,2 – 3,11
		Gender (M/F)	6 / 6	6 /6	7 / 5
5-Year Olds	Immediate	n	12	12	12
		age (yrs, months)	5, 2	5, 3	5, 2
		range (yrs, months)	5,0 – 5,4	5,0 – 5,6	5,0 – 5,4
		Gender (M/F)	4 / 8	10 / 2	5 / 7
	Delay	n	12	12	12
		age (yrs, months)	5, 3	5, 3	5, 2
		range (yrs, months)	5,0 – 5,5	5,0 – 5,6	5,0 – 5,4
		Gender (M/F)	4 / 8	9 / 4	4 / 8

Materials

The experimenter used a puppet (a ginger cat) to interact with the children. Four unfamiliar artefacts were used with each child: a metal, yellow, four-way radiator key, a green round plastic air-vent cover, a blue spiky tumble-dryer ball, and a red tile adhesive spreader with a box to keep them in (Figure 3.1). Each of the artefacts were of a similar size and could easily be held in one hand. The target artefact was counterbalanced between children. There were also four coloured card swatches to match the colour of the artefacts and black and white photographs of each of the artefacts to match the shape. The experimenter used a ‘music box’ (never labelled) to demonstrate the action and function of the artefacts. This was secretly activated via a foot pedal under the table so it appeared that the target artefact had started the music playing.

Figure 3.1: Novel Artefacts Used in Experiments 4 – 9.



Procedure

Each child was invited to play a game individually with the experimenter (E) in a quiet corner of the classroom. E introduced herself and her friend Mittens (the puppet), and asked the children if they would help her teach Mittens all about different shapes and colours by playing a game (all the children agreed). The overall structure of the task was: the warm-up task, first distractor task, exposure session, second distractor task, and test session.

As a *warm-up task*, E asked the children to help her get all of her things out of the box individually and put them on the table. As they did this, E recorded the participant’s details allowing them freedom to inspect each artefact in their own time. During the *first* *distractor task* E laid the black and white photos of the four novel artefacts on the table in front of the child, and explained that they were teaching Mittens about shapes. She asked the child to match all the artefacts by placing them on top of the picture that looked the same. After the child had matched all four artefacts, Mittens appeared to whisper in E's ear, to which she replied, "Ok but we have to use the Koba" (demonstrating the novel name) whilst selecting the target artefact.

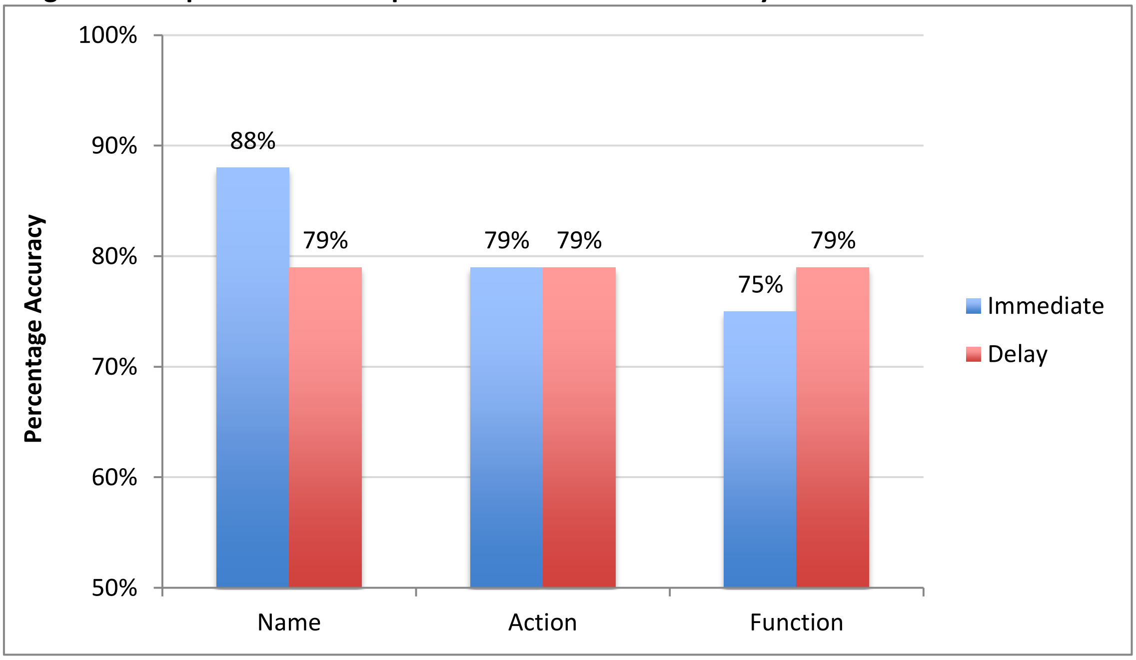
This marked the start of the *exposure session*. The target artefact was counterbalanced across participants, once selected E then 'bounced' it along the top of the music box making contact with it three times in a straight line (demonstrating the novel action). As the target artefact was lifted from the surface of the music box on the third bounce, E pressed a foot pedal (unobserved by the participant) to activate the music (demonstrating the novel function). This was a 20 second sound clip from a popular children's television theme tune. As the song finished, Mittens "whispered" to E for a second time to which she replied, "Ok, but this is the last time, we have lots to do. We have to use the Koba", thus repeating the name and going on to demonstrate the action and function a second time. After Mittens whispered a third time she replied, "No, we have too much to do" and put the music box away under the table. This removed the substrate from view in a way that would make sense to the participant.

The child was then engaged in a *second distractor task*, and asked to match the four artefacts to cards of the same colour, and to name the colours out loud for Mittens to hear. For children in the immediate condition, the *test session* followed directly after the second distracter task, whereas children in the delay condition were tested six to seven days later. In the test session, with the four novel artefacts (but not the substrate) on the table, children were asked one of three questions depending on the experimental condition. In the naming condition they were asked, “Which one is the koba?”; in the action condition they were asked, “Which one do we do this with?” (pantomiming the novel action); and in the function condition they were asked, “Which one starts the music playing?” After their help children were thanked and told they could return to playing in the nursery or classroom.

3.2.3 Results

The data obtained in Experiment 4 were very clear (Figure 3.2). In all six conditions, most children correctly selected the target artefact (75% - 88%). Using binomial distribution calculations (chance performance, 1 of 4 novel artefacts), performance was well above chance in all six conditions ($p < .001$).

Figure 3.2: Experiment 4 – Graph to Show Retention Accuracy Across Conditions.



Although not expecting any interactions when observing the raw data, a hierarchical four-way log–linear analysis (Time Interval, Information Type, Age and Accuracy) produced a final model that did not retain any significant main effects or interactions. The likelihood ratio of this model was χ^2 (16) = 1.043, *p* > .999, indicating that the model was a good fit of the data.

Further log-linear analyses were run to check for any unexpected interactions between artefact, gender or age group and accuracy. A four-way log–linear analysis produced a final model that did not retain any significant main effects or interactions. The likelihood ratio of this model was χ^2 (36) = 11.329, *p* > .999, indicating that the model was a good fit of the data.

3.2.4 Discussion

Children in this study, in both immediate and delay conditions were able to successfully comprehend artefact names, actions and functions after a brief incidental exposure. These data suggest that children are excellent learners of all knowledge needed for artefact use (name, action and function) – supporting previous research (Casler & Kelemen, 2005). The current experiment extends this previous research by providing the most convincing evidence to date that children can fast map this information.

These data suggest that children's learning of artefact function is as good as their action and word learning. This is striking, when the greater complexity of function is considered. Functions must be inferred, rather than merely perceived (as with actions and words). Likewise, at test, children are presented with the pantomimed physical action and spoken word. In contrast they a give a verbal summary of the function (i.e., “Which one starts the music playing?”). The experimenter did not speak these words during the exposure session. It is up to the child to realise that the words spoken by the experimenter at test relate to the function that they observed during exposure. Children’s ability to recall their fast mapped function knowledge is therefore particularly impressive.

It could be argued that there are different learning mechanisms working in my fast mapping task; for example, one processing words and one processing actions and functions. However, there is nothing in my data, from any of the first four experiments, to suggest that one specific mechanism is used to learn artefact names (i.e., words), and that a different one is used to learn artefact action and functions.

My data suggest that learning artefact action and function can be just as impressive as words. In fact, recent research on word learning has suggested that children do not always fast map words (e.g., Horst & Samuelson, 2008; Vlach & Sandhofer, 2012). For example, in Horst and Samuelson (2008), 2-year-olds were introduced to novel artefacts and their names using a single exposure on a standard referent selection task. The children were shown a tray containing three artefacts, two familiar and one unfamiliar, and asked to pass the experimenter the "fode". The children were successful at the referent selection tasks, but after a five-minute delay, were generally unable to extend, produce or even simply retain this information. These results were consistent across Horst and Samuelson's first three experiments in a series of four. It wasn't until the final experiment, where they included an *ostensive* naming condition (the experimenter very explicitly labelled the novel artefact whilst holding it), that they saw any evidence for retention after a delay.

More recent research suggests that fast mapping is context dependent. Children can fast map words very effectively, but it is dependent on the way that the novel information is introduced (Vlach & Sandhofer, 2012; Holland, 2015). How did I obtain such effective retention of artefact names (action and functions) after a one-week delay, when researchers such as Horst & Samuelson (2008) saw none after five minutes?

Horst and Samuelson's used a referent selection task, which I did not. My thesis investigates the fast mapping of the knowledge needed to use of artefacts: name, action and function. I wished this information to be presented in a context in which children are likely to learn most of their artefact knowledge. That is, for children to incidentally observe a novel artefact being used, and being named as part of that use. This kind of casual observation was not consistent with a referent selection task. In contrast, in a referent selection task, just one piece of information is used to exclude a familiar artefact and select a novel one. This approach does not fit with the incidental observation of a novel name, action and function together. A particular problem is that the experimenter would have to verbally describe the novel function (e.g., selecting between scissors and a novel artefact, the experimenter would say “Give me the one we use to make the music play, not the one we use to cut paper”). I did not want to verbally describe this function; I wanted children to observe it being produced.

Perhaps children are particularly inclined to learn information presented when a novel artefact’s use is observed. Children in a western, artefact rich environment, need to learn a lot about artefact use. Incidental observation of artefact use may activate fast mapping.

3.3 Experiment 5: Investigating the Effect of Number of Demonstrations and Verbal Labelling on Long-Term Comprehension

3.3.1 Introduction

In Experiment 5 I wanted to create a more demanding test of function comprehension. Although ceiling performance in the previous experiment demonstrated young children’s ability to learn about artefacts, I needed some poor performance in order to dissociate artefact name, action and function learning. In Experiment 5 I focused on children’s learning of function in the long term, and made two manipulations in an effort to obtain 'some poor performance' on my fast mapping task. I considered that testing function learning in the long-term was likely to be the most demanding combination.

The two manipulated variables were: number of demonstrations during exposure (Single-Demo versus Two-Demos) and the verbal labelling of the target artefact (With-Label versus No-Label). In a 2x2 factorial design children were allocated to one of four experimental conditions (No-Label, Single Demo; No-Label, Two-Demos; With-Label, Single-Demo; With-Label, Two-Demos). If I observed poor performance on one or more of these four conditions, this would provide a methodology for comparing name, action and function learning. Thus creating a more stringent methodology for future experiments, and possibly resulting in dissociation between these three kinds of artefact information.

As discussed, previous mutual exclusivity research suggests that children understand that each category has only one label, as such they will avoid attaching a second label to a familiar category (Halberda, 2003; Markman et. al 2003). This mutual exclusivity principle is also suggested to prime learning novel artefact names on the premise that hearing a novel label for a novel artefact draws attention to a new category to be learnt. For example Mather and Plunkett (2010) found that even at 10-months-old infants' interest in novel artefacts was increased after hearing a novel name. If artefacts are not labelled in the two no-label conditions, this may make children less likely to attend to new information (i.e., the artefact's shape and the action and function associated with it). Will this in turn make them less likely to retain this information under conditions of minimal, incidental exposure?

Also, are two demonstrations of artefact use required during the exposure session or can a single demonstration lead to long-term retention? Vlach and Sandhofer, (2012) found that with only a single demonstration at exposure children were able to correctly comprehend a target artefact in the immediate condition, but not after one week. Part of the difficulty associated with incidental learning, is that by definition the learner does not know that some new information is about to be presented. A potential problem with this is that by the time the learner has realised that new information is being presented, the opportunity to attend to it properly has already passed. In the task used in the previous experiment, children may not have realised that the action and function associated with a novel artefact was being demonstrated until the first demonstration was completed. This may have interfered with their ability to encode this information. However, in the previous task, the action and function were then demonstrated a second time. Children may have then been ready to encode this information – making a link between the target artefact, action and function. With just a single demonstration, children would not get the opportunity.

More generally, I have noted that even fast mapping of artefact names is not guaranteed – and seems to depend on exactly how the new information is presented (Horst & Samuelson, 2008). It was therefore possible that the two manipulations used in Experiment 5 could affect children's ability to retain functional information after a brief incidental exposure and a one-week delay.

3.3.2 Method

Participants

Participants were drawn from the same sample as the previous experiment (although had not been previously tested). There were 100 participants, aged 4 & 5-years-old, (range 4; 3 - 5; 4, mean age 4; 11), 47 boys and 53 girls. See Table 3.2 for further breakdown.

Table 3.2: Experiment 5 – Table to Show Age and Gender Breakdown Across Conditions.

No of Demo.	Measure	With Label	No Label
Single Demonstration	N	25	25
	Mean age (yrs, months)	5, 0	4, 10
	Age range (yrs, months)	4,5 – 5,4	4,3 – 5,2
	Gender (M/F)	13 / 12	12 / 13
Two Demonstrations	N	25	25
	Mean age (yrs, months)	5, 0	4, 11
	Age range (yrs, months)	4,4 – 5,3	4,5 – 5,4
	Gender (M/F)	9 / 16	13 / 12

Design

This experiment used a between-participants 2x2 factorial design. The independent variables were label (With-Label / No-Label) and number of demonstrations (Single-Demo / Two-Demos). Children were unsystematically allocated to one of four experimental conditions (No-Label, Single Demo; No-Label, Two-Demos; With-Label, Single-Demo; With-Label, Two-Demos). The dependent variable was comprehension accuracy.

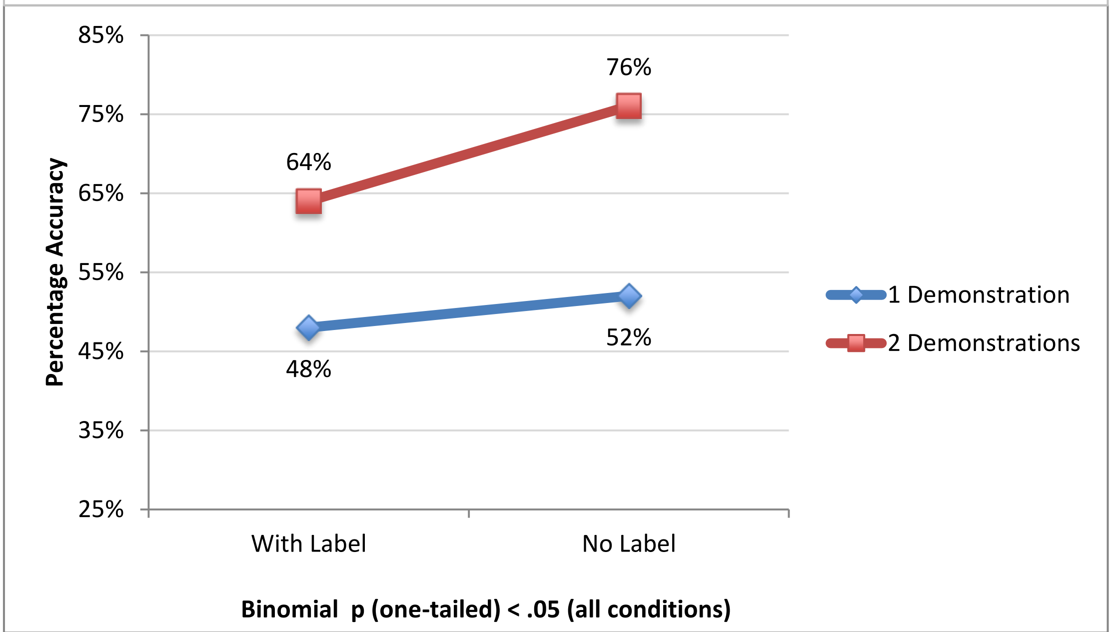
Materials and Procedure

The methodology was identical to that of Experiment 4 until the exposure session. Mittens appeared to whisper in E's ear but at this point the children either heard "Ok but we need to use the Koba" in the 'with label' condition or "Ok but we need to use this one" in the 'no label' condition. Similarly, in the two-exposure condition as in the previous experiment, E continued to demonstrate the action and function again for Mittens a second time before putting the music box away. Whereas, in the one-exposure condition, after the first time the music played the experimenter skipped straight to putting the music box away. The same distractor task was then completed and all the children were sent back in to the nursery to play. The testing session occurred 6 – 7 days later and all the children were asked "Which one makes the music play?"

3.3.3 Results

Primarily a series of binomial analyses tested whether the children had successfully recalled the target artefact at levels above chance (1 in 4, 25%). Across both demonstration and label conditions the children recalled the target artefact after a weeks' delay to levels above chance (all *ps* < 0.05). However, on first inspection it appears that children's ability to retain functional information is not affected by whether or not they hear a label but may be affected by whether children saw one or two demonstrations (see Figure 3.3).

Figure 3.3: Experiment 5 – Graph to Show Retention Accuracy Across Conditions.



Using 3-way, hierarchical, log-linear analysis, the overall model was not significant (Label*Demonstrations*Accuracy: χ^2 (1) = 0.245, p = 0.621). When examining the eliminated effects we also established that there were no significant differences or interaction effects in the label conditions (Label*Accuracy: χ^2 (1) = 0.667, p = 0.414). These results suggest that whether or not children heard the name of the artefact, this did not affect their ability to retain or recall other information needed for use. However, there was a significant interaction between the number of demonstrations and accuracy in selecting the target artefact. (Demonstrations*Accuracy: χ^2 (1) = 4.167, p = 0.041). Retention was reduced when children only saw the artefact demonstration once. A further 3-way log-linear analysis found no significant gender or age group differences or interactions (gender*age group*accuracy: χ^2 (1) = 0.108, p = 0.742).

3.3.4 Discussion

Even under these more challenging conditions (fewer demonstrations and without the target artefact being labelled) children were still able to retain the artefact-function mapping at levels significantly above chance. Once again this would suggest children's ability to fast map artefact information for use is well developed. However, the log-linear analysis demonstrates that retention was far poorer with only a single demonstration than with two.

Perhaps as Vlach and Sandhofer (2012) suggest, reducing the number of exposures weakens the memory trace. Although they investigated this by comparing six explicit, demonstrations at exposure to just one incidental demonstration – so the difference between their two conditions was much greater than mine. It is also is possible that children in a single demonstration condition did not know new information was being presented until the opportunity to attend to it had passed – interfering with their ability to encode this information. In the two demonstrations conditions the action and function were then demonstrated for a second time enabling them to make the link between the target artefact, action and function.

In contrast, the children's retention was unaffected by whether or not they heard the novel artefact labelled. They did not need to hear a novel name to recognise that there was novel artefact information to learn. Thus children do not require an artefact to be labelled in order to direct them to learn the action and function associated with it. With hindsight, it is perhaps unsurprising that children's fast mapping of the actions and functions associated with artefacts is unaffected by whether or not they are named during use. Adults are probably not likely to name an artefact they are using (or about to use), they just 'get on' and use them. It would be rather limiting if children only fast mapped action and function when a novel artefact was also named.

I have now obtained some poor performance on a fast mapping task. Can we use this task to produce a dissociation between children's learning of artefact name, action and function knowledge?

3.4 Experiment 6: Investigating Fast Mapping of Artefact Information for use Under Conditions of Reduced Exposure

3.4.1 Introduction

Having seen from Experiment 5 that 4- and 5-years-olds found the methodology with only one demonstration during exposure more challenging, this experiment tested 3-year-olds to see whether, in this more difficult learning environment, we would find a dissociation between information types when testing comprehension. We hoped that under more difficult testing conditions with reduced demonstrations during exposure we would be able to tease apart the different information categories necessary in knowledge for use. Having seen no significant difference between the immediate and delay data in the previous experiments, and as I believe to demonstrate learning children must be able to retain and recall information after a delay, all children were tested in a 'delay' condition, 6 – 7 days after exposure. I felt that if the accuracy results in one information type were higher this would indicate a more salient feature and potentially suggest which information type was assimilated first.

To test the generalisability of my findings, a different substrate and function were used in this experiment. Using a second substrate, demonstrating a second function, tested whether these effects would extend beyond the music box used previously. In the drawer-box condition the experimenter performed the specific action (bouncing along the top of the box three times), using the target artefact to open a drawer in the side of the box. This drawer was once again operated by a hidden foot pedal. Half the children performed this task, and half the children were tested with the music box as before.

3.4.2 Method

Participants

All the children attended nursery schools and permissions were granted following the same procedure as previous experiments. Data were collected from 60 3-years-old (mean 3 years 6 months, range 3;1 – 3;11) 35 male and 25 female (see Table 3.3 for a further breakdown).

Table 3.3: Experiment 6 – Table to Show Age and Gender Breakdown Across Conditions.

Substrate	Measure	Name	Action	Function
Music Box	N	10	10	10
	Mean age (yrs, months)	3, 5	3, 7	3, 7
	Age range (yrs, months)	3,1 – 3,10	3,2 – 3,11	3,3 – 3,11
	Gender (M/F)	8 / 2	5 / 5	7 / 3
Drawer	N	10	10	10
	Mean age (yrs, months)	3, 6	3, 6	3, 6
	Age range (yrs, months)	3,1 – 3,11	3,1 – 3,10	3,2 – 3,10
	Gender (M/F)	4 / 6	6 / 4	5 / 5

Design

This experiment used a between-participants design. The independent variables were information type (name / action / function) and substrate (music box / drawer). The children were unsystematically allocated to one of the six experimental conditions to test the dependent variable, comprehension accuracy.

Materials

For the music box conditions the experimenter used the materials as in the previous experiments: a puppet (a ginger cat named Mittens), 4 unfamiliar artefacts and a box to keep them in, four coloured card swatches, four black and white photographs of the novel artefacts and a 'music box'. In the drawer conditions the experimenter used the same 4 artefacts, photographs and colour swatches but instead of a music box had a wooden box with a hidden drawer that popped open when secretly operated by foot pedal (as music box), inside the drawer was a necklace.

Procedure

The first half of the experiment followed the same procedure as the previous experiments. Children were engaged in the warm-up task and first distractor task leading to the exposure session where mittens “whispered” in the experimenter’s ear to which E responded, “Ok but we need to use the Koba”.

Music Box task: As before, the experimenter then selected the target artefact and bounced it along the top of the music box 3 times, pressing the secret foot pedal to activate the music (a 20 second sound clip from a popular children’s television theme tune). As the song finished Mittens “whispered” to E for a second time to which she replied “No, we can’t do it again, we have lots to do!” and put the music box away under the table (removing the substrate from view to prevent any visual memory cues or associations during testing).

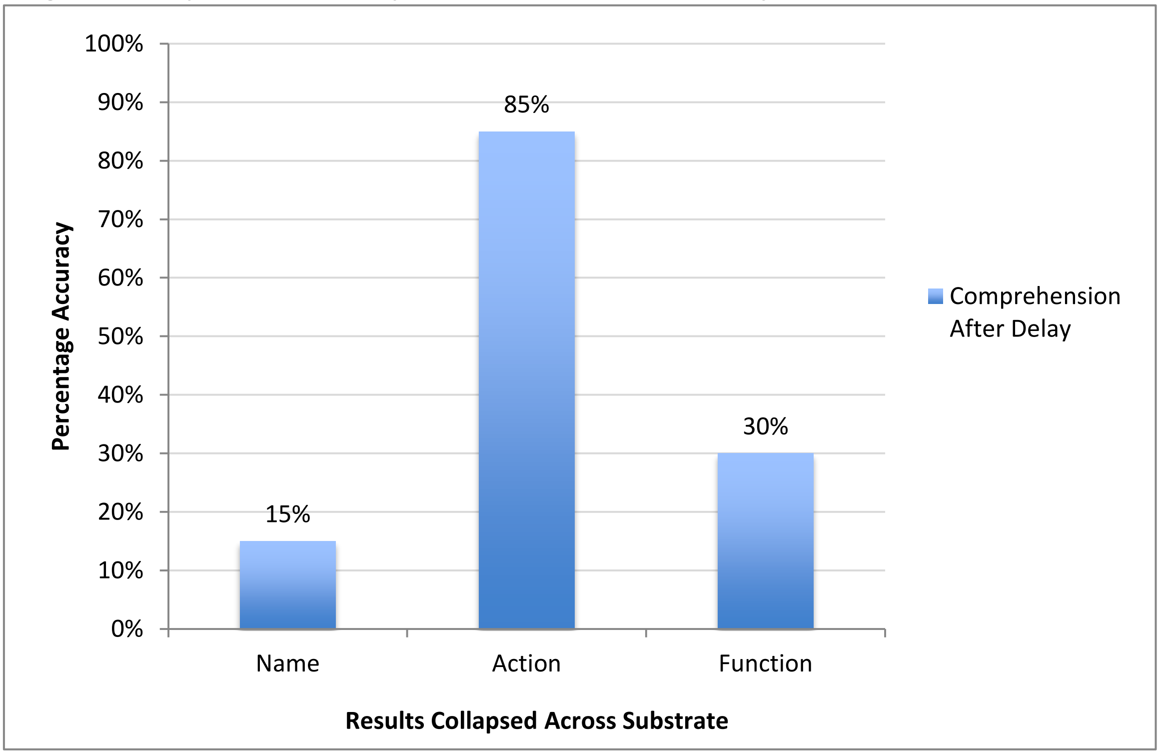
Drawer Box task: The drawer condition was identical apart from the substrate. E similarly selected the target artefact and said, “Ok, but we need to use the Koba” and bounced it along the top of the drawer box 3 times. Unseen by the child, the experimenter pressed the foot pedal that activated the drawer release. The drawer opened and the experimenter took a necklace from it, which she placed around the puppets neck. As before, Mittens “whispered” to the experimenter again, but she said “No, we can’t do it again, we have lots to do!” and placed the drawer-box on the floor under the table (removing the substrate from view).

In both conditions, the children were then engaged in the second distractor task and the testing session followed 6 – 7 days later. During the testing session, with the original four novel artefacts on display, children were asked one of three questions depending on their experimental condition allocation. In the naming condition they were asked, “Which one is the koba?”, in the action condition “Which one do we do this with?” (pantomiming the action) or in the function condition “Which one starts the music playing?”.

3.4.3 Results

As you can see from Figure 3.4 we have a large disparity between the results of the knowledge type conditions. Action information appears notably easier for the children to learn (retain and recall) than both name and function information under these more challenging exposure conditions.

Figure 3.4: Experiment 6 – Graph to Show Retention Accuracy Across Conditions.



Running a 3-way, hierarchical, log-linear analysis, the overall model was not significant (substrate*information type*accuracy: χ^2 (2) = 3.122, p = 0.210). Examining the eliminated effects indicates no significant interaction between the substrate used and accuracy (substrate*accuracy: χ^2 (1) = 1.745, p = 0.186). However, a significant interaction was found between information type and accuracy (information type*accuracy: χ^2 (2) = 23.857, $p < .001$).

Chi squared analysis further confirms that the only condition in the model that has a significant effect on comprehension accuracy is information type (information type * accuracy: χ^2 (2) = 22.127, $p \leq 0.001$). Running binomial distribution analyses, only children in the action condition recorded accuracy levels that found them successfully selecting the target artefact significantly more often than chance, set at 25% (action exact binomial, $p < .001$). A final Chi-squared analysis revealed no significant differences between gender (χ^2 (1) = 0.380, p = .538).

3.4.4 Discussion

Using the original fast mapping methodology (two incidental demonstrations during one brief exposure) young children were able to retain and recall all novel artefact information at the same rate (Experiment 4). However, once we increased the demands of the task, children only retained one type of information: action. Examining 3-year-olds on a comprehension test, following a single demonstration of use during the exposure session, produced good retention of the artefact-action mapping, but poor retention of the artefact-name and artefact-function mappings. This indicates that children may find it easier to learn the actions associated with artefacts than their functions and names. Moreover, these findings were replicated when using a new function and substrate. There were no significant differences found between the music box and drawer box conditions. I have not pursued this further in my thesis but future research will be needed to investigate the extent to which my findings generalise to other artefact-substrate-functions combinations.

Finally, I do not claim, based on these data, that children *always* learn artefact-action mappings after one demonstration, and artefact-name and artefact-function mappings after two. Many other factors will influence children's learning about artefacts. Sometimes children will recall all three kinds of information, and other times they will learn nothing. However, my data suggest that action learning is favoured over name and function learning. So if children are only going to remember one mapping after observing a novel artefact name, action and function, it seems likely to be the artefact-action mapping that is retained. Once children can successfully understand and comprehend this artefact information, it is then necessary to learn how to replicate and produce it for themselves.

3.5 Experiment 7: Investigating Production of Fast Mapped Artefact Knowledge

3.5.1 Introduction

Ultimately, to successfully use an artefact in an 'adult like' fashion you must not only be able to understand its name, action and function, but be able to produce them yourself. In the word learning literature several studies document how *hard* children find word production following brief incidental exposures, even when comprehension is good (e.g., Carey & Bartlett, 1978; Heibeck & Markman, 1987; Childers & Tomasello, 2002). As previously mentioned, there is little prior research into children's comprehension or production of action (and function). There are two key articles that have previously investigated action production: Childers and Tomasello (2002) and Hahn and Gershkoff-

Stowe (2010). Neither of these studies meet my definition of fast mapping (see section 1.2.1); and used actions that were arguably functionless (see section 2.5). My Experiment 7 is the first to test of production following fast mapping observing an artefact in use, with an action that produces an obvious function.

The first to investigate learning of artefact action were Childers and Tomasello (2002). Under various training conditions children were taught either six novel words (six nouns or six verbs) or six novel actions through ostensive labelling of a novel artefact; children were tested on both comprehension and production. In the comprehension condition, children were very good at recalling the target artefacts in all word and action conditions. However, children were able to reproduce more novel actions more accurately than they were able to reproduce novel words (nouns and verbs). In the verb condition, children often reproduced the physical action represented by the verb, instead of the word label. The second article, Hahn & Gershkoff-Stowe (2010), compared the mappings of novel artefacts' names and actions. Immediately after the exposure session children were assessed on their comprehension and production knowledge. The young children, as expected, passed comprehension tests for both conditions, but whilst being able to successfully produce the many actions, they produced far fewer names.

I compared comprehension and production using the earlier fast mapping methodology from Experiment 4. Having found no significant difference between comprehension accuracy for names and action, would the same pattern be observed for production accuracy? I compared actions and names, but not functions. It is impossible to *produce* a function independent of an action. A function is the goal achieved by making a specific action with a specific artefact on the appropriate substrate. In terms of 'real life' use, we start with a function or goal in mind (e.g., slicing bread from a loaf) and select the correct artefact (e.g., a bread knife) and perform the correct action (e.g., a sawing motion) to achieve it. As such, we would be unable to ask children to physically produce the function without them reproducing the action – and if they produce the action It is impossible to be sure whether they expect the function to be its consequence. Although, asking children to describe an artefact's function in words is 'sort of' producing its function, it relies on children's ability to translate their understanding of function into a coherent description. I felt that as this could be a challenging task for young children, the data were likely to under-estimate their function knowledge.

Using the fast mapping methodology from Experiment 4, 4-5-year-old children were given the same incidental demonstrations during exposure, and during testing were asked only one question (depending on their allocated condition). A 2x2x2 factorial design was used with, information type (name vs. action), test type (comprehension vs. production) and time delay (immediate vs. delay). I hypothesised, based on previous studies, that the comprehension of both name and action would remain good: however, that action production would be better than name production. Having observed no difference between immediate and delayed comprehension in Experiment 4, I had no grounds to predict differences in production in this experiment. Nevertheless it was worth testing both time delays, as I could potentially obtain a dissociation in either – depending on the difficulty of the task.

3.5.2 Method

Participants

128 four and 5-year-old children took part, (range 4;1 - 5;4, mean age 4;8), 63 boys and 65 girls (see Table 3.4). As in Experiment 4, all children were from a primary school in

Greater London. As before, permission was given by both head teachers and class teachers and parents were given the opportunity for their children to opt out of the study. Additionally, at this school parents had already signed permission slips allowing their children to be photographed and filmed at school.

3.4: Experiment 7 – Table to Show Age and Gender Breakdown Across Conditions.

Test Type	Time Delay	Measure	Name	Action
Comprehension	Immediate	n	16	16
		Mean age (yrs, months)	4,9	4,8
		Age range (yrs, months)	4,7 – 5,1	4,3 – 5,4
		Gender (M/F)	10 / 6	9 / 7
	Delay	n	16	16
		Mean age (yrs, months)	4,10	4,8
		Age range (yrs, months)	4,6 – 5,1	4,2 – 5,0
		Gender (M/F)	5 / 11	7 / 9
Production	Immediate	n	16	16
		Mean age (yrs, months)	4,8	4,7
		Age range (yrs, months)	4,4 – 5,2	4,1 – 5,2
		Gender (M/F)	6 / 10	9 / 7
	Delay	n	16	16
		Mean age (yrs, months)	4,8	4,8
		Age range (yrs, months)	4,4 – 5,1	4,2 – 5,2
		Gender (M/F)	8 / 8	9 / 7

Design

The experiment used a 2x2x2 factorial design. The independent variables were information type (name / action), task type (comprehension / production) and time interval (immediate / delay). The dependent variable was comprehension and production accuracy.

Materials and Procedure

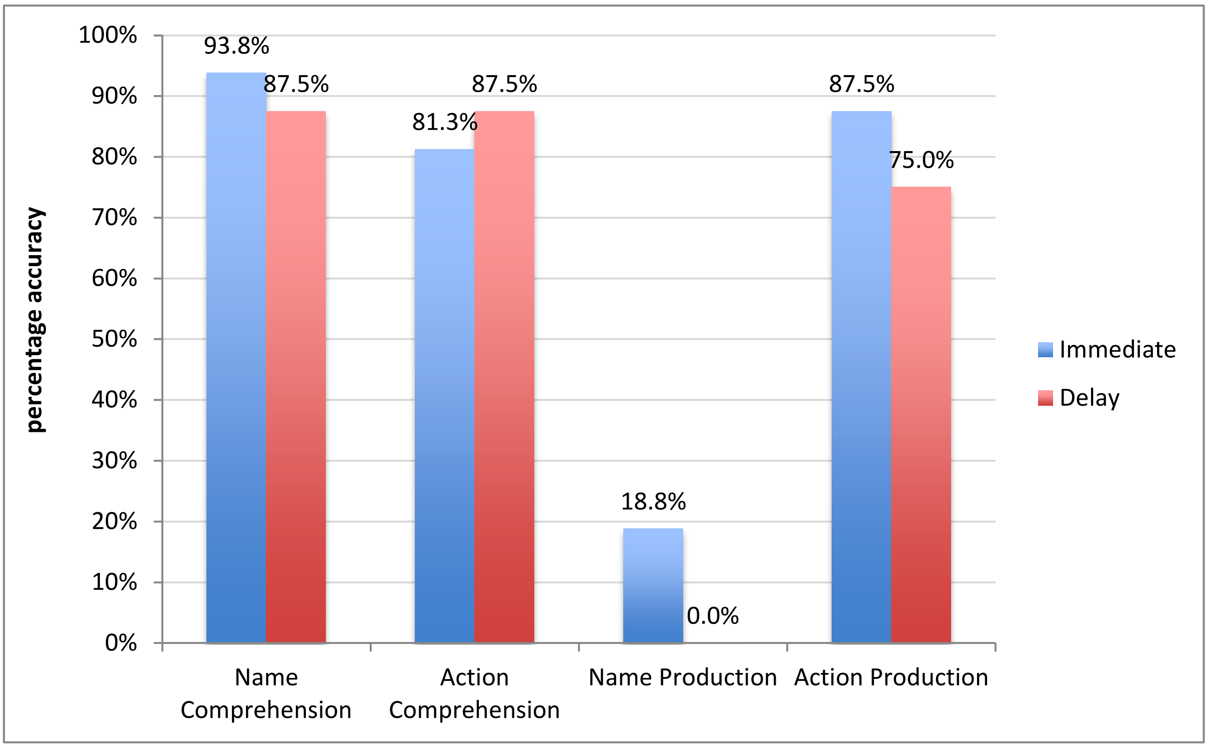
All the materials and procedure were identical to the previous experiment until the testing session. Once again children were unsystematically allocated to the immediate or delay condition and asked either of following questions (depending on their allocated condition) whilst the experimenter was holding the target artefact: “Can you tell me what this is called?” and “Can you show me how you use this?” The responses to the action question “Can you show me how to use this?” were filmed so if necessary, a second experimenter could confirm the correct actions were performed.

3.5.3 Results

Merely looking at the percentage accuracy scores (Figure 3.4), we can already see a large difference between comprehension and production results. The comprehension results replicate that of Experiment 4, each condition were equally successful in retaining and recalling the correct information. However, in the production data we can see that there was a strong difference between name and action conditions when asked to reproduce the information.

Only three children produced names that replicated the original: koba, kuba and kaba. Two children produced names that were similar but ultimately incorrect: skuba and kroba and three children gave the artefact a new name of their own: poppal, quata and pepi. Five children named the artefact based on its appearance: green circle, ball, helicopter, fan, and spiky ball. The remaining 19 children gave no response, mostly remaining silent following the experimenter’s question.

Figure 3.4: Experiment 7 – Graph to Show Percentage Accuracy Results Across Conditions.



As clearly visible in Figure 3.4, the children found it far easier to replicate the action they had seen rather than the name they had heard. It was not possible to analyse a four-way log-linear model (information type, time interval, test type, accuracy), as there was no variance in the delayed name production condition (no one produced the name after a delay). However, a preliminary chi-squared test revealed no significant association between time interval and accuracy (χ^2 (1) = 0.876, p = 0.349) allowing data across this variable to be collapsed.

A three-way log linear analysis included information type (name or action), task type (comprehension or production) and accuracy produced a final saturated model retaining a three-way interaction between task type*information type*accuracy: χ^2 (1) = 17.451, p < 0.001. To break down this effect, individual chi square tests were performed. As expected we saw significant associations between accuracy and test type, whether the children undertook comprehension or production tasks (χ^2 (1) = 25.530, p < 0.001). Also finding a significant association between accuracy and information type, whether they were asked to recall artefact name or artefact action. (χ^2 (1) = 15.444, p = 0.001). The odds ratio is a useful measure of effect size, in this instance we can see that children are likely to produce a novel action 25 times more, than they are likely to produce a novel word.

As before, running a final three-way log linear analysis age group*gender*accuracy we found no significant differences or interactions between any of the participants' naturally occurring groups (χ^2 (1) = 0.537, p = 0.467).

3.5.4 Discussion

Experiment 7 investigated comprehension and production accuracy. As with the previous comprehension data from Experiment 4, these data suggest that young children are able to of fast map artefact names and actions after a brief, incidental exposure and demonstrate their knowledge in a comprehension test one-week later. Also as with previous data, there were no significant differences between the immediate and delay condition. These data suggest that, when it comes to a test of comprehension, children's memory is relatively stable over a week.

In contrast, there were significant differences between artefact name and action production. Perhaps most strikingly, children were unable to reproduce the name even in the immediate condition. Whereas, children in the action production condition were still able to successfully produce the target action after a one-week delay. In addition, there appears to be no loss of information for action production after a long-term delay. If children had mapped the action in the short-term, it appears it was retained for the long-term. Thus my data suggest that children's ability to produce artefact actions is substantially better than producing artefact names.

It is difficult to assess the rate of loss of information loss for name production, as children were unable to produce the name even in immediate condition. It is worth noting that even this condition included a short delay as a distracter task followed the exposure session. It would be interesting to compare performance immediately after exposure, to that following the distracter task. This would indicate whether children are able to successfully produce the name after just hearing it and then, whether there is rapid information loss even during the short delay of the distractor task.

Although I hypothesised that action production would be better that name production, what is surprising was size of the difference. This striking difference is even more pronounced than in Hahn and Gershkoff-Stowe (2010). If even two demonstrations can lead to near perfect action production, then in previous studies with more demonstrations (e.g. approximately six times in Hahn & Gershkoff-Stowe, 2010), researchers may have under-estimated the difference between action and word production results.

So why do we find such disparity between the production but not comprehension of actions and names? The following discussion considers the complexity of the stimuli (actions versus words) and the relationship between their input and output representations (e.g., seeing making an action versus hearing speaking a word). This analysis is speculative, although there are data from other literatures to support it.

Firstly, it could be that actions are just simpler than words. One way to explain why words are so hard to produce relates to their complexity (Simpson, Cooper, Gillmeister & Riggs, 2013; Simpson & Carroll, 2014). Words are more complex than actions, because they comprise a very precise series of transient phonemes produced at speed. It has been long established that humans cannot distinguish non-speech sounds presented at the same speed at which phonemes are produced in words during typical speech (Liberman, 1957). It may therefore be very difficult for children to encode all the phonemes in a novel word with sufficient precision for them to be able to produce it. Nevertheless the word representation may be sufficiently detailed to pass a comprehension test – with children remembering the artefact that was named and having some idea of word used. In contrast the action used in my task (e.g., three bounces on the upper surface of the music box) was simpler and produced more slowly than the word. It may be much easier to create a sufficiently detailed representation of this action, and so output it in the production test.

Imitation research suggests that when children (.g., Taylor & Diamond, 1996; Simpson & Riggs, 2011) and adults (for a review see Brass & Heyes, 2005) watch an action, this automatically activates an output representation of this action. The discovery of mirror neurons (Rizzolatti, 1992; Iacoboni et al., 1999) goes some way to explain why seeing an action may automatically generate an output representation of that action. Neuroscientists discovered that the motor system is activated both when making the actions and experiencing them. This would suggest that, in my task, when children see the novel action performed with a novel artefact, a representation of how to produce this action is formed. Thus when seeing the artefact again, this motor representation is available to be produced.

Recent research has suggested that the link between the sound of a word and the motor gesture used to make it may also be automatically activated with the discovery of echo neurons (Kohler, Keysers, Umilta, Fogassi, Gallese, & Rizzolatti, 2002). In addition several studies *with adults* have suggesting that perceiving speech sounds does indeed activate the motor code associated with those sounds (Kohler et al., 2002; Watkins, Stafella & Paus, 2003; Fadiga et al., 2002). However studies conducted with children have found no evidence for such automatic activation (Simpson, et al., 2013; Simpson & Carroll, 2014). Simpson and colleagues compared automatic activation of actions and words in children.

They obtained evidence that actions were automatically activated while words were not. This is consistent with the proposal that seeing an action generates an output, motor representation of that action, but hearing a word does not generate such an output representation.

At present it is not clear why the action production is so much better than word production following fast mapping. One possibility is that seeing an action generates a motor representation that can be used in a production test; whereas hearing a word generates no such representation. This difference may be related to the great complexity of words.

3.6 General Discussion

3.6.1 Summary of Results

This chapter aimed to investigate learning of the information required to use artefacts. In Chapter 1 I discussed that we need to know information about an artefact's name, action and function as a prerequisite for using it and understand how it works. Chapter 2 results indicate that children are able to fast map novel artefact name and action. Using the same stringent definition of fast mapping (incidental learning, minimal exposure and long-term retention), Chapter 3 investigated whether this would extend to learning artefact function. The methodology for Experiment 4 used substrate (music box), action (bounce along the top of box), name (koba) and function (making the music play). It was carefully designed to allow 'real-world' brief, incidental observation of a novel artefacts use. This procedure facilitated direct comparison of name, action and function. Comprehension tests suggested that young children are good learning all this artefact knowledge: with excellent performance in both the immediate and delay conditions (after a week). I saw no significant differences between the name, action and function data.

In Experiment 5 the exposure conditions were manipulated: whether the novel target artefact was labelled and the number of demonstrations (one or two), to see if either would affect long-term retention of the artefact-function mapping. Children's results were not affected by whether or not the experimenter labelled the novel artefact. In both the with-label and no-label condition children were able to recall the target artefact at levels significantly above chance after a one week delay. However, results were affected when children only saw one demonstration of the artefact in use. Although children recalled the target artefact at levels above chance in both conditions, children who saw two demonstrations recalled the target artefact significantly more than children who saw only one demonstration. Experiment 6 aimed to obtain a dissociation between artefact name, action and function learning. The more challenging, single demonstration during exposure was used, and performance compared on two substrates (a music box and a drawer box). No significant differences were found between the two substrates – providing initial evidence that my results are generalisable. With regards to information type, only the artefact-action was retained after a week, performance on the name and functions conditions was no better than chance.

In Experiment 7, using the same methodology as Experiment 4, children were tested on naming and action production. As with Experiment 4 there were no significant differences between the immediate and the delay conditions, children either performed well or poorly in both conditions. Comprehension results matched that of Experiments 2 and 4, children were successful at selecting the target artefact in both the immediate and delay conditions. However, production results demonstrated that 75% of children could still successfully produce the novel artefact's action after a week's delay; only 19% could produce its name even in the immediate condition. Whilst children had mapped the information sufficiently well to pass a comprehension test, production of the novel artefact action was clearly much better than production of the novel artefact name.

In short, two key findings have emerged regarding artefact information learning. Firstly, that following a strict fast mapping regime children *can* rapidly learn artefact mappings to name, action and function. However, if this ability is put under real pressure – by providing just a single presentation of the novel artefact information or by asking children to produce rather than just comprehend the information – then it breaks down. Under the most stringent tests children seem to remember the artefact-action mapping, while forgetting the name and function mappings.

3.6.2 Action Learning and Embodied Cognition

In the most challenging conditions children only retain the artefact-action mapping. Why is this the case? Theories of embodied cognition suggest that children first learn about the world through sensorimotor input and only later turn this knowledge into a conceptual representation (e.g., Boncoddo, Dixon & Kelley, 2010; Lockman, 2000). Embodied cognition was first historically proposed by Herbart (1825) but arguably, it is with Piaget (1952), that this idea is most clearly applied to child development. Embodied cognition researchers now consider sensorimotor input to be a crucial element in the processes by which children acquire knowledge and achieve representational changes (e.g., Lockman, 2000; Rakison & Woodward, 2008; Hahn & Gershkoff-Stowe, 2010).

Embodied cognition theorists propose that action provides the foundation for the development of conceptual representation. Lockman (2000) proposes that early motor skills of neonates and young infants develop into early instances of artefact use. Motor patterns produced in early infancy are then repeated as infants start to interact with objects. For example hand to mouth action develop to enable infants to feeding themselves (Connolly & Dalgleish, 1989), or a side to side action becomes the first mark making behaviour and will in time lead to drawing (Palmer, 1989). Having mastered these (relatively) simple sensorimotor skills, infants are then ready to focus on the affordance of artefacts and problem-solving tool use (Lockman, 2000). In time, I believe, these sensorimotor skills can help young children to make sense of many of the artefacts that they see adults using (Sommerville, Woodward & Needham, 2005). This notion of sensorimotor foundation extends to young children learning novel words; they derive meaning and learn artefact names using the same systems to assimilate novel word information to previously stored sensorimotor representations. Moreover, this works bi-directionally, when retrieving a word, the sensorimotor representations associated with it are also activated (e.g., Barsalou, 2008; Glenberg & Robertson, 2000; Glenberg & Kaschak, 2002).

Recent research suggests that the effect of action on cognition continues well beyond infancy (Hahn & Gershkoff-Stowe, 2010; Boncoddo, Dixon & Kelley, 2010). With regards to artefact use, it is suggested that artefacts are represented through the patterns of activation elicited in the sensorimotor system. As an example, Boncoddo, Dixon and Kelley (2010), investigated the role of action in the emergence of new representations in 3- to 5-year-old participants using gear-system problems. They suggested that children of this age would not spontaneously understand the physics behind a series of gears (i.e., gears in direct contact turn in opposite directions). They hypothesised that children would need to follow the direction of the gears turning by physically using their hands to the direction of movement of the arrows. They found that the more children used this manual force-tracing method, the faster they understood how the gears worked. Boncoddo and colleagues (2010) suggested that their results supported the embodied cognition proposal that new conceptual representations emerge from physical interactions with the environment and are ultimately grounded in action.

Looking at the results from this chapter, it appears that young children are *most* receptive to artefact action knowledge. Broadly these data are therefore in keeping with the embodied cognition approach. If, as my data suggest, children may learn the actions associated with artefacts first, the first representation that a child has of a novel artefact may contain a mapping between the artefact's shape and the action made with it. More information about the artefact's name and the function that it performs may only be added later.

The Next Chapter

To investigate this further I examine young children's category formation. For children to form artefact categories, they have to recognise similarities in artefact characteristics. Firstly, I establish which artefact information children see as characteristic features of an artefact. Experiment 8 investigates whether children will demonstrate mutually exclusive behaviour with regards to an artefacts name, action and function. If children were reluctant to attach more than one name/action/function to a novel artefact, it would suggest that they see these features as *characteristic* of that category.

Experiment 9 uses a forced-choice procedure to establish which of these characteristic features children deem definitive. That is, which feature defines category membership? Young children are often seen to categorise by shape, however there is an on-going deliberation as to why this occurs (Cantrell & Smith, 2013; Booth 2014). The

Attentional Learning Accounts (ALA) and Shape-as-Cue Accounts (SCA) contest whether shape is a cue to an artefact's name or its function. There is evidence that children will categorise simply by shape (e.g., Smith, Jones & Landau, 1996). Others suggest that when function is clear and plausible, young children will categorise using function (e.g., Kemler Nelson, 1999). However, no previous research has considered action (embodied cognition theories) to be a feature that children may use to categorise artefacts. In Experiment 9 I investigate this possibility.

Chapter Four

Do Children Regard Action and Function as Defining or Merely Characteristic Features of an Artefact Category?

4.1 Introduction

Data from the previous chapters suggest that children can fast map a variety of information, notably, artefact name, action and function. However, this is not the case for all novel information (Riggs, Mather, Hyde & Simpson, 2015; Holland, Riggs & Simpson, 2015). It has been suggested that children will only fast map “socially transmitted information” (Bloom, 2000; Childers & Tomasello, 2002). This socially transmitted information includes the names, action and functions associated with artefacts. Clearly, names can only be learnt from other people. Likewise, information made available when an artefact’s use is demonstrated (i.e., action and function), is not available again without further demonstrations, and thus should to be mapped efficiently as soon as it is observed. In contrast, placing a sticker on an artefact is stored visually in its environment. Placement of a sticker on a novel object has previously been used to investigate what children will, and in this instance, won’t fast map (Markson & Boom, 1997; Riggs et al., 2015). Potentially in a week’s time that sticker will still be in place, so there is no need to retain that information when one can simply see it again.

Another significant feature of the type of information children will fast map about artefacts, is that it is all relevant to artefact categories (Childers & Tomasello, 2003; Riggs et al., 2015). Usually, the name, action and function associated with an artefact are properties common to all the items that belong to that artefact’s category. Maybe children simply learn the information that is most reliably associated with a category. There is little point trying to retain information that is only relevant to an individual item that you may never encounter again, it is more important to remember information that is relevant to all items of a particular kind. This would suggest that children understand (if perhaps only implicitly) that an artefact's name, action and function are characteristic features of the artefact's category.

Initially we need to examine exactly what information children understand to be a characteristic feature of an artefact kind. What information do they believe to be an intrinsic feature of the artefact, consistent across other category members? By 'category-characteristic' information, I do not necessarily mean information that is category defining (i.e., information that *must* be true of an item for it to belong to a category). When it comes to artefacts, it is possible that name, action or function, are all category-characteristic information. One way to examine this is to investigate whether children apply the principal of mutual exclusivity to this information.

It is well established that children will not attach more than one name to an artefact kind (Markman, 1990; Golinkoff, Mervis & Hirsh-Pasek, 1994; Diesendruck & Markson, 2001; Riggs et al., 2015). An artefact's name is seen to be a characteristic feature of that category. It is socially agreed, enduring and extendable to other within-category members (Golinkoff, Mervis & Hirsh-Pasek, 1994, Waxman & Booth, 2000; Childers & Tomasello, 2003; Riggs et al., 2015). Riggs, Mather, Hyde & Simpson (2015) obtained evidence consistent with children applying a similar mutually exclusive principle with regards to artefact action in referent selection tasks. In Experiment 1, I obtained evidence consistent with children applying the similar mutually exclusive principle to artefact action in referent selection tasks. In Experiment 2 I obtained evidence that children can fast map this information and extend it (i.e., apply it to other category members) with long-term retention. We have similarly demonstrated fast mapping and long-term retention of function, but do children show mutual exclusivity with function as well?

4.1.1 Mutual Exclusivity and Referent Selection Tasks

The term 'mutual exclusivity' has previously been strongly associated with word learning principles. Fast mapping was also initially believed to be specific to word learning; however, we have now found it applies to artefact information needed for use. Perhaps we should think of 'mutual exclusivity' as the domain-general behaviour of only attaching one piece of category-characteristic information to a category.

As with a discussion on fast mapping, there are two main accounts used to explain mutual exclusivity. The first is a domain specific approach, suggesting mutual exclusivity is a behaviour unique to word learning and the acquisition of lexical categories. Certainly, when learning a novel word, children by two years of age seem to understand that one cannot attach more than one label to each artefact (Markman & Wachtel, 1988; Golinkoff, Mervis & Hirsch-Pasek, 1994; Merriman & Bowman, 1989). That is to say, when given one familiar and one unfamiliar artefact and presented with a novel name, children in their second year will assume that the unfamiliar label attaches to the unfamiliar artefact (17 months – Halberda, 2003; 18 months – Markman, Wasow & Hansen, 2003; 24 months – Horst & Samuelson, 2008).

The second explanation follows a domain general approach, suggesting that this mutually exclusive behaviour will be observed with any category-characteristic information. There is clear evidence that children apply the mutual exclusivity principle to artefact actions in a referent selection task (Experiment 2, Chapter 2; Riggs, Mather, Hyde & Simpson, 2015). Indeed, children seem to apply the mutual exclusivity principle to *any* information that can be used to distinguish two items in a referent selection task. For example, Diesendruck and Markson (2001) detail three studies in which three-year-olds are given referent selection tasks and asked to identify the target exemplar based on a novel label or a novel fact. The children were shown two novel artefacts; the experimenter labels one (e.g. zev) or tells the children a novel fact about it (e.g. my sister gave me this). Children are then asked to pass the artefact with a different label (e.g. bem) or expressing a new fact (e.g. my dog likes to play with).

Diesendruck and Markson (2001) observed that children were equally reluctant to attach two facts to an artefact, as they were two names. They suggest children take a socially pragmatic approach to novel artefact information, which results in a mutually exclusive behaviour. Simply, if the experimenter had meant for me to select the first artefact then they would have used the same name they labelled it with (or the same fact expressed) before. Once a child has observed an adult attach a fact to an item, they then expect the same fact to be used to label that item in future. If a different fact is then mentioned, children tend to assume that it must apply to another item – leading to mutually exclusive behaviour with facts.

Results from an action referent selection task (Riggs, Mather, Hyde & Simpson, 2015) indicate that children must possess a similar level of understanding that each artefact will have its own specific action. As such, children demonstrate similar mutually exclusive behaviour when encountering action-based referent selection tests. We have demonstrated an understanding that an artefact's action is normative and enduring (consistent after a week's delay) as children extend this novel action mapping to novel exemplars within the same category (Experiment 2, Chapter 2; Riggs, Mather, Hyde & Simpson, 2015; Childers & Tomasello, 2003). Moreover, these data suggest that children demonstrate mutually exclusive, one-to-one mapping (one artefact has one action) with regards to artefact action (Experiment 3, Chapter 2; Riggs Mather, Hyde & Simpson, 2015). When shown a second novel action, children avoided selecting the original novel target and instead selected an alternative novel artefact.

4.1.2 Testing Mutual Exclusivity and Function using Referent Selection

Children demonstrating mutually exclusive behaviour indicate an understanding of a one-to-one correspondence between an artefact and characteristic information (e.g., one artefact-one action). Ultimately, I want to know if children understand there is a one-to-one correspondence between an artefact and a function? No one has previously tested mutual exclusivity of function using referent selection tasks. However, some research provides evidence of mutually exclusive behaviour using other tasks, outlined below (e.g., Casler & Kelemen, 2005; Casler, Terizyan & Greene, 2009; Defeyter & German, 2003; Casler, 2014).

Casler and colleagues (2005, 2007, 2009) have previously investigated what children understand about the properties of an artefact's function. Casler and colleagues believe young children display evidence that they understand artefacts are made for *something*, even if they do not yet know what that something is (Casler, Terizyan and Greene, 2009). Casler and Kelemen (2005 – methodology detailed in section 3.1.1; 2007) demonstrated a novel artefact performing a novel function, in the presence of physically similar foils. They found that when asked which item was needed for achieving the demonstrated novel function, children as young as 2-years-old would repeatedly select the target artefact, even if alternative artefacts with the same physical affordances were available. Casler and Kelemen (2005) suggest that after just one exposure to an adult intentionally using a novel artefact children rapidly and enduringly construe that artefact as *for* that specific function. This certainly indicates that children are beginning to understand a specific artefact-function correspondence.

Casler, Terizyan and Greene (2009) aimed to investigate young children's awareness of artefact function exclusivity. Two and 3-year-olds were shown four familiar and four novel artefacts, and their functions demonstrated by an experimenter (E1). The children were also invited to try the function for themselves. A second experimenter (E2) then entered (having not seen the original demonstrations) who wanted to demonstrate the function themselves. In two of the demonstrations, E2 attempted to use the artefact in a way that directly contravened E1's use (e.g. a key stirring food). The children's behaviour was examined to see if they reacted to the incorrect usage (e.g., did they try to show E2 how to use it correctly or laugh at them doing it wrong?). After each trial the children were asked what each item was for, to test to see if they treated E2's demonstrations as the artefact's intended use.

Overall, when asked what each item was 'for', both 2- and 3-year-olds reported E1's original demonstrated use, suggesting once again that children understand an artefact to be for a specific function. Regarding the second novel action of E2, 3-year-olds' behaviour consistently suggested that E2 was perceived as 'wrong'. This included directly reporting to E1 about E2's errant actions, attempting to teach E2 how to do it right, and questioning E2's behavior (this behaviour was less marked in 2-year-olds). Moreover, this was consistent for both the familiar artefacts, with well-known functions, and the novel artefacts, whose functions they had just learned. Casler, Terizyan & Greene (2009) suggest that by two years of age children are *starting* to develop this understanding of exclusive artefact-function use. They propose that it is not yet a complete or a 'robust grasp' but that this was more pronounced by 3-years-old.

Casler and colleagues' data (2005, 2007, 2009) suggest that at two years of age, children have not yet formed exclusive artefact-function correspondence. Specifically, although consistently choosing the target artefact to perform the original function, 2-year-old children would not always reject it when asked to perform a second function. However, by the age of 3-years-old, children are beginning to understand that an artefact's function is both stable and exclusive. Reviewing Casler and colleagues work (2005, 2007, 2009) would suggest that this understanding strengthens between the ages of 2- and 5-years-old. It appears that once children *do* understand an artefact's function, it is clear it should not have a secondary function- its function is fixed; indicative of a one-to-one artefact-function correspondence.

Once again using a different approach (to both my referent selection tasks and that of Casler and colleagues), other researchers have investigated this 'functional fixedness' (German & Defeyter, 2000; Defeyter & German, 2003; Defeyter, Avons & German, 2007). German and Defeyter (2000) describe functional fixedness as a behaviour demonstrated when participants are "hindered in reaching the solution to a problem by their knowledge of an artefact's conventional function" (p. 707). In other words, when children's one-to-one artefact-function correspondence is fixed, they then struggle to use an item to perform a *second* function to solve a problem.

Defeyter and German (2003) tested 5- and 7-year-olds using problem solving tasks. The children were required to inhibit the conventional use of an artefact to successfully solve a problem, using its features in an unconventional manner. They suggest that the more concrete the children's understanding of functional fixedness the longer it will take to inhibit the tool's conventional function and complete the task. This is exactly what they found; the 5-year-old children were faster at completing the task as they were less constrained by a tool's normative function. For children to complete the functional fixedness task successfully, it required them to override their usual mutually exclusive behaviour in order to, if only temporarily, attribute a second use to a single artefact. This was easier for the younger, 5-

year-old participants, suggesting that this one-to-one artefact-function correspondence is not yet fully defined. The children's results suggest that this deeper understanding of artefact function is not fully developed until approximately 7-years-old.

In line with Defeyter and colleagues' view that this one-to-one view of function is not developed in younger children, more recently, Casler (2014) has reported an investigation suggesting 2-year-olds do *not* utilise a mutually exclusivity principle with regards to artefact functions. Over the course of two days children took part in a series of trials testing whether they apply mutual exclusivity to novel names, facts and functions. Children were shown two novel artefacts. In the function condition, the first artefact was demonstrated fully performing a function (e.g., striking a bell). Initially, no function was demonstrated with the second artefact, but it was wrapped in paper to increase salience. A cracker was placed on the table between the two artefacts. The experimenter then shielded the cracker and artefacts with a large screen, and crushed the cracker. The experimenter ensured an artefact banged the table, so children could hear there was a tool in use, and not simply the experimenter's hand. The screen was then removed to reveal the end state of crumbs, but without revealing which artefact had been used. The experimenter placed both the bell box and a new cracker on the table with both the artefacts and asked the children "Can you show me how to do it?" The children could choose to either crush the cracker or ring the bell. Later a different colour 'dax' was included to test for extension.

Casler (2014) found that two-year-olds did not show mutual exclusivity with function. In fact 92% of children returned to the *first* artefact (the one whose function had been demonstrated), when asked to perform the *second* function. In contrast young children *did* show mutual exclusivity with both names and facts (e.g., My mum gave it to me). Casler (2014) concluded that although 2-year-olds are efficient mappers of artefact function, they do not demonstrate mutually exclusivity with this kind of artefact knowledge (i.e., one artefact - one function) – as older children and adults do. Casler suggests her data are consistent with the proposal that function learning does not use the same mutual exclusivity principle as fact and name learning.

Overall, the data described in this section suggest a developmental increase in children's understanding of artefact function as an enduring and exclusive characteristic feature. Perhaps children are only able to form more general conceptual understandings around the age of 3-years-old (e.g., artefacts are made for something), but do not fully develop a concrete one-to-one correspondence of artefact-function fixedness until around 7-years-old.

As the methodologies in these previous experiments can be quite complex, I decided that seeing how children respond in a simple referent selection task makes a good starting point. In Experiment 8 I endeavour to administer a clear and definitive test of mutual exclusivity in young children using a referent selection task. Improving the methodology from Experiment 1 children were tested with both familiar and unfamiliar artefact information. I aim to replicate the results from Riggs et al. (2015) with artefact actions and similarly test for demonstrations of mutually exclusive behaviour with regard to artefact functions.

4.2 Experiment 8: Do Young Children Treat Action and Function as Characteristic Features of an Artefact Category in a Referent Selection Task?

4.2.1 Introduction

In Experiment 8 I investigated two questions. Firstly, do children have a novelty bias or do they use the principle of mutual exclusivity in referent selection tasks with artefacts? In Experiment 1 I tested children with a novel name or action and this led to the selection of a novel artefact. This behaviour could reflect the application of mutual exclusivity or it could simply reflect a preference for picking a novel artefact – irrespective of how it was labelled. To distinguish these two possibilities in the current experiment I used both novel and familiar artefact information. If children consistently selected the unfamiliar artifacts, regardless of the familiarity of the artefact information, it would suggest that children were applying a simple novelty bias. For a mutually exclusive behavior to be demonstrated, children in the familiar condition should choose the familiar artefacts, and children in the novel condition should choose the novel artefacts.

Secondly, do children treat names, action and functions as equally characteristic of an artefact category? If name, action and function are all seen as category-characteristic features, then they should all be used in a referent selection task – to select the familiar artefact when a familiar piece of information is used, and a novel artefact when a novel piece of information is used. If children do not see these as typical characteristics, then the novel name, action and function could be attached to either the familiar or novel artefact at random.

There are some data to suggest that younger children treat artefact functions as category-characteristic features, perhaps even category defining features (e.g., Casler &

Kelemen, 2005; Casler, et al., 2009). However, there are also data that suggest children do not treat functions as category-characteristic features until middle childhood (e.g., Defeyter & German, 2003; Defeyter, et al., 2007). In this experiment I tested 3-year-olds on a referent selection task, so it was difficult to know what to predict based on the literature from other tasks.

4.2.2 Method

Participants

Data were collected from 60 children, 31 boys and 29 girls, aged three to four years old with a mean age three years and eight months (for further breakdown please see Table 4.1). All the children were enrolled in nursery classes at a Greater London Primary School. Both head teachers and class teachers gave permission for their pupils' participation and then parents were given the opportunity for their children to opt out of the study.

Table 4.1: Experiment 8 – Breakdown of Age and Gender of Participants.

Measure	Familiar Information	Novel Information
n	30	30
Mean age (yrs; months)	3; 9	3; 8
Age range (yrs; months)	3; 3 – 4; 3	3; 3 – 4; 2
Gender (M / F)	14 / 16	17 / 13

Design

This experiment used a mixed design. The independent variables were familiarity (familiar information / novel information) and information type (name / action / function). The variable of familiarity was assessed between participants; the children were unsystematically allocated to one of two experimental conditions (familiar information / novel information). Each child (in both groups) performed three separate trials, in a counter-balanced order encompassing the within-participants variable of information type (name / action / function). Their judgements were recorded to examine the dependent variable of novelty selection.

Materials

Six artefacts were used during the experiment. There were three familiar artefacts (a key, a cup and a spoon), and three novel artefacts (a four-way radiator key, an adhesive spreader and a plastic air vent. The artefacts were grouped into a familiar and novel pairings as follows: 1) Large metal key & red plastic adhesive spreader, 2) Small plastic cup & green plastic round air vent cover and 3) Metal dessert spoon & black metal four-way radiator key. Each pairing was placed into a paper gift bag. The bags were of different sizes (small, medium and large), so that the experiment could ask the participant to look in a specific bag. The experiment also required colouring pencils and paper for the children to draw around their selected artefacts.

Procedure

All the children were tested individually with the experimenter in a quiet corner of their classroom. The children were invited to play a drawing game with the experimenter. The children were allowed to pick their favourite colour pencil and were asked to draw around the experimenter's hand as a warm-up task. The children's attention was then drawn towards three bags, each different in size and each containing one of the three pairs of artefacts. All children completed three trials, each trial focused on one information type (name, action or function). At the beginning of trial the children were asked to select one of the bags (small, medium or large), remove the artefacts and put them on the table.

Table 4.2: Experiment 8 – List of Procedural Questions.

Artefact	Name	Action *Pantomiming action*	Function
Novel	Please can you pass me the koba?	Please can you pass me the one we do this with? *Rub artefact on arm*	Please can you pass me the one we use to clean a toaster?
Key	Please can you pass me the key?	Please can you pass me the one we do this with? *Pantomime turning key in lock*	Please can you pass me the one we use to open doors?
Spoon	Please can you pass me the spoon?	Please can you pass me the one we do this with? *Pantomime scooping soup to mouth*	Please can you pass me the one we use for eating?
Cup	Please can you pass me the cup?	Please can you pass me the one we do this with? *Pantomime lifting cup to mouth*	Please can you pass me the one we use for drinking?

Children in the familiar information condition were given demonstrations matching the familiar artefact (the target artefact's name, action or function), and children in the novel information condition were given novel demonstrations on each trial. There were six different kinds of request that the experimenter made – familiar name, familiar action and familiar function or novel name, novel action and novel function. The same novel name, novel action and novel function questions were used for each child in the novel information condition. The artefacts were similarly counterbalanced in the familiar information condition; as such name, action and function questions were prepared for each of the three familiar artefacts. The order in which the pairs were presented, the information type order and thus, which artefact pairs were attached to each information type, were counterbalanced to prevent any order or artefact bias. The 12 questions asked (name, action and function for each of the three familiar artefacts plus the novel name, action and function questions) are listed in Table 4.2.

Once the children had selected the artefact they were then asked to draw around it, this also created a record of their selections. The child then helped tidy the artefacts back into the bag and proceeded with the next trial.

4.2.3 Results

For children to demonstrate mutually exclusive behaviour they should select the familiar artefact when presented with a familiar word, action or function. In contrast, when presented with a novel word, action or function, children should select a novel artefact. As seen in Table 4.3, the majority of children demonstrated this mutually exclusive behaviour at levels above chance (50%) for all information types (binomial analysis, p<.001). Overall 92% of all participants demonstrated mutually exclusive behaviour selecting the familiar artefact in the familiar condition and the novel artefact in the novel condition.

Table 4.3: Experiment 8 – Number of Participants Demonstrating Mutually Exclusive Behaviour Across Conditions.

Information Type	Familiar Information	Novel Information
Name	30/30*	29/30*
Action	27/30*	25/30*
Function	27/30*	28/30*

*exact binomial *p* (one-tailed) < 0.001 (all conditions).

Further chi-squared analysis did not show any significant differences between the familiar or novel conditions for each information type: Name, χ^2 (1) = 1.017, p = .313; Action, χ^2 (1) = 0.577, p = .448; Function, χ^2 (1) = 1.017, p = .301. Furthermore, there were no significant differences in the overall amount of children performing mutually exclusive behaviour in the novel or familiar conditions: χ^2 (1) = 0.083, p = .773. Following this, McNemar's tests examined any differences between information types. Similarly we saw no significant differences between information types (see Table 4.4).

Table 4.4: Experiment 8 – p value Results from McNemar's Analyses.

	Name versus Action	Name Versus Function	Action Versus Function
Familiar	p = .250	p = .250	p > .999
Novel	p = .219	p > .999	p = .219

These results support the Experiment 1 data (Chapter 2) and replicate Riggs, Mather, Hyde and Simpson (2015), in that when faced with a novel action, children once again excluded for potential referents any artefact whose use they were already familiar with. Moreover, we have now seen this extended to artefact function information.

4.2.4 Discussion

These results would certainly corroborate that children display a certain level of functional understanding by the age of 3-years-old. It appears that children will demonstrate equally mutually exclusive behaviour with regards to artefact name, action *and* function. This behaviour suggests that children do have some understanding that an artefact's name, action and function are all consistent and enduring characteristic features across within category members. If not, children would have been more willing to attach an unfamiliar function to a familiar artefact. Moreover, we are able to dismiss an attention to novelty explanation (as suggested after Experiment 1), as the children in the familiar condition did not simply pick the novel artefact.

What cannot be discussed following these data alone is how children's mutually exclusive reasoning is developed. As detailed in Chapter 2 (Section 2.1.1) there are a number of proposed principles in explanation for mutual exclusivity (ME), each precipitates the same outcome – children will attach a novel name to a novel artefact. As before, the aim of this research wasn't to investigate which theory offers the best explanation of the observed behaviour. These results simply indicate that this phenomenon extends beyond words to artefact actions and functions. Discussion hereafter of 'rejecting the familiar artefact' or 'selecting the novel artefact' is not indicative of an opinion on the process, merely the result.

These results are consistent with the results from Experiment 1 (Chapter 2) and replicate those in Riggs, Mather, Hyde and Simpson (2015) finding that children will demonstrate mutually exclusive behaviour when observing artefact action. We can now further suggest that both artefact function and action were treated with equal regard to artefact name. This would certainly suggest that pre-school children seem to understand that artefacts have a specific name, action and function. Whilst children understand that an artefact should not have two names, they will also only attribute one action and one function to an artefact.

However, these results initially appear inconsistent with Casler (2014), who reports that children *were* more willing to use an artefact to perform a second function. Casler took a very different approach to this investigation; as such there are a few methodological differences that could explain the differences in results. Firstly, there appears to be an inequality in the approach towards each of the three information types she examined (name, fact and function). It is the differences in results that lead Casler to conclude against a general learning model yet it could the differences in exposure accountable.

In the first experiment, the approach to testing was unbalanced. Children were asked a comprehension question regarding name and fact and then asked to produce the function. We know from both the research detailed in Chapter 3, and previous rapid learning research (Childers & Tomasello, 2002; Hahn & Gershkoff-Stowe, 2010), that production is likely to be a harder task. Moreover, a great deal more information is required to produce a function than comprehend a name. To produce the function the child will need to have encoded the tool, potentially the substrate, the physical action and the function (thus substrate change) and recalled all of that for successful re-use. This would be particularly difficult when they did not see the second demonstration of the tool, its action or its function.

Casler explains that had function been merely explained ("This tool is for ringing bells") that essentially the function task would not have differed from the fact task. However, in a second experiment function *was* examined as a comprehension test (functional fact condition) but this time, the exposure was further reduced. In the second experiment, children did not see any of the functional demonstration. The two-year-old participants had to infer it. As proposed in the previous chapter, potentially something about seeing a tool in use (a demonstration of its full action and function on a substrate) helps map its correct information for use. By occluding or not completing the tool functional demonstrations of either of the novel artefacts, maybe children did not reach the same level of understanding. Perhaps a condition that allowed demonstration of the tool in use but then tested all the information types equally using a comprehension question would have returned different results.

The method for Experiment 8 was far simpler than in Casler (2014), perhaps allowing clearer interpretation as a result. As children knew the function of the familiar artefacts they were then reluctant to attach a second function (action or name). Instead when presented with novel function information, children readily chose a novel artefact as the referent for that function.

Contrary to Casler's (2014) suggestion, these results suggest that there could be an underlying general learning process used to support artefact name, action and function learning. In these referent selection tasks children were as quick to attribute a novel function to a novel artefact, as they were a novel name or action. They rejected artefacts for which they already knew these features, thus demonstrating mutually exclusive behaviour. Although these results suggest children are starting to develop a one tool – one function rule, we cannot go as far as to suggest a fully concrete functional fixedness. This would require further investigation; perhaps a good place to start would be to replicate Experiment 3 (Chapter 2) with regards to functional information.

Although demonstrating mutually exclusive behaviour is indicative of category formation, it is not a complete reflection of it. Referent selection tasks require an immediate, online judgement to be made when faced with two artefacts. This automatic judgement allows novel information to be rapidly attributed to a novel artefact. The referent selection data indicate that three-year-olds have some basic understanding that artefacts have a specific name, action, and function. Understanding that these features are characteristic suggests that they are consistent across that artefact kind to other members of its category. However, success at a referent selection task does not require learning, simply understanding. The fast mapping data (Chapter 3) show children can *learn* this artefact information for use after a brief exposure and retain it.

Mutual Exclusivity could be the link between learning and categorisation. In order for children to learn about artefacts in the real world, a mutually exclusive understanding is necessary to map novel information to novel artefacts. This prevents errors of over attaching novel information onto existing familiar artefacts. However, in order for this to occur, mutually exclusive behaviour requires an immediate, online judgement to occur, as is also required in categorisation tasks.

Referent selection tasks make use of features that are characteristic of a category. However, despite the results from experiment 8, this does not furnish proof that children understand the *specific* one-to-one correspondence. Moreover, although it appears reasonable that children understand that name, action and function are characteristic features of artefacts, it does not tell us which of these information types is the *defining* feature of their category. Categorisation tasks make use of features that define a category. Name, action and function cannot all be definitive as what would happen if they were placed in direct conflict?

Artefact categorisation tasks typically manipulate artefact features putting different components in conflict with one another. For example shape vs. colour, size or texture (Landau, Smith & Jones, 1988; Smith, Jones, Landau, Gershkoff-Stowe & Samuelson, 2002) or shape vs. function (Gentner, 1978; Smith Jones & Landau, 1996; Kemler Nelson and Students, 1995; Kemler Nelson, Russell, Duke & Jones, 2000). It could be argued that, as shape so often affords function, (as recognised in the Shape-as-Cue Account) that putting shape and function in direct conflict with one another is not an ecologically valid way to assess categorisation. However, forced choice tasks are the only way to directly test and compare the different characteristic features that may be utilised during categorisation to see which of these features is deemed definitive.

4.3 Experiment 9: Do Children Treat Shape, Action or Function as Defining Features of an Artefact Category in a Forced-Choice Selection Task?

4.3.1 Introduction

Chapter 1 included a more detailed account of the background literature regarding children's artefact categorisation. I detailed the occurrence of a shape bias in young children and the two leading accounts in explanation. Firstly, an Attentional Learning Account which dictates that children attend to shape as a cue for an artefacts name and thus, its category. Secondly, the Shape-as-Cue Account which suggests that children attend to shape as a cue to an artefact's function, which in turn dictates its category. For more information please return to sections 1.5.2 through 1.5.5.

For the remainder of the introduction I will introduce a proposal for potential categorisation using action as the definitive feature. I will then outline concerns with previous categorisation methodologies, before outlining the design for my own method.

Categorisation Using Action

No one has ever tested whether children (or adults) will categorise artefacts using action information. If, as suggested from fast-mapping data in previous chapter, that children can learn action information first, in a rapid learning environment would children first notice and thus use action as a criteria for discerning novel artefact categories? As mentioned in the previous chapter, an embodied cognition approach to learning suggests that children learn about the world through their actions in it. Lockman (2000) suggests that a link between artefacts and actions start developing early in the first year of life. Perone, Madole, Ross-

Sheehy, Carey and Oakes (2008) state, “Action shapes how people experience the world and come to represent its contents.” (p. 1242).

Perone et al. (2008) use 6-7-month-old infant participants to investigate the relationship between activity with artefacts and attention to artefact appearance. For the infants observing an action on an artefact, the action itself was more salient than the artefact appearance. Moreover, once the infants had interacted with the artefact it predicted their response to a novel artefact. Perone et al. (2008) suggest these results implicate emerging action systems as a mechanism for integrating information about artefact action and artefact appearance.

They further suggest that the process of linking the appearance of artefacts with the types of actions performed is integral to recognising artefacts. Moreover, these actions may help infants learn important links between how an artefact appears and how it is used. Perhaps, if artefact action is of primary importance to assimilating artefact information (young children attach artefact shape and function knowledge to a particular action), this will emerge as the defining feature in young children’s categorisation.

Thus far, no categorisation study that examines artefact shape versus artefact function as definitive for categorisation, accounts for artefact action. Returning back to the beginning of this debate Gentner (1978) briefly mentions actions. She discusses Clark’s (1973) and Nelson’s (1973) opposing views, reflecting that Nelson (1973) points out children are strongly interested in actions and functions asking questions such as “what is it?” and “what does it do?” Nelson (1973- cited in Gentner, 1978) suggests that children first learn the words for artefacts that they can physically act upon. She goes on to suggest that “Both theories hold that an artefact's normal motion is likely to be included in its early meaning, since motion is both perceptually salient and functionally important” (p138). It appears that

Piaget's (1954) theories of learning via action in the world were considered vital to the learning of artefact function. However, as Piaget's views went out of favour, action information also seemed to be less considered leaving simply artefact function and shape to be debated.

Researchers since make little to no mention of action, it appears they have always included action to be part of a functional understanding rather than as a separate characteristic feature. With a new resurging interest in children's artefact learning with regards to artefacts and their actions, perhaps we will see new understanding of the two features both separately and together. This experiment aims to establish how children will define categories when we directly compare shape, action and function?

Methodological Concerns

When designing the methodology it is important to review previous studies and address any methodological concerns, aiming to create as unbiased an approach as possible. It has been suggested that the conflicting results regarding- at the most basic level- shape versus function in early categorisation, can simply be attributed to methodologies and interpretations. Diesendruck, Hammer and Catz (2003) quite boldly suggest that none of the aforementioned studies provide unbiased or definitive contributions regarding physical or functional similarity to children's artefact categories.

Diesendruck et al. (2003) suggest that many categorisation studies possess potential physical and functional imbalances. Either functional information was not plausible or not explicitly available (Smith et al., 1996). Or it was overtly described thus making it the more salient feature (Diesendruck et al. 2003; Kemler Nelson, Frankenfield et al., 2000). Deák, Ray and Pick (2002) similarly note that adults repeatedly demonstrating particular features are unwittingly indicating their intentions or desires, inadvertently guiding the child to select that attribute when generalising.

To ensure methodological impartiality, I tried to ensure each function was equally salient, plausible and understandable for a three year-old (turning on a light and sounding a buzzer). Similarly, ensuring that both the artefact actions received the same level of attention regarding time and dexterity (bouncing three times along the top of the box and rubbing in three circles in the front of the box). The artefact shapes were distinctly different (one cross and one circle), and neither one afforded an action or a function so that each information type could be assessed individually at test.

To address this further, taking inspiration from the fast mapping exposure (Experiment 4 & 6), it was essential that each artefact was observed in use. Furthermore, that each characteristic feature (shape, action and function) was demonstrated equally and simultaneously so there is no methodological bias. Similarly, the experimenter must not draw particular attention to any one feature making it more salient, thus reducing experimenter bias. Moreover, although every artefact will perform a clear action resulting in an obvious function, the artefact shape must not afford its action or function. This enables testing to clearly differentiate what purposeful decisions the participants made. The children initially observed the experimenter demonstrating an artefact in use (stating its name then performing a specific action on the substrate to produce an obvious function).

Finally, I felt that not naming the original artefact would be biased against an ALA approach to categorisation as the nature of the theory is a word learning account. Although, Experiment 5 data (Chapter 3) indicated that naming an artefact did not have any effect on whether an artefact was fast mapped, and similarly Diesendruck and Bloom, 2003 did not find naming prevented artefact categorisation, I was reluctant to have any methodological bias.

Bloom (2000) discusses how some of the methodologies previously used in the exploration of infant categorisation can allow the results to be interpreted to support either an ALA or SCA argument. For example, examining language errors: ALA theorists propose that these are demonstrative of a word and category learning approach bound primarily to shape (historically: Clark, 1973; Behrand, 1988). It is often observed that children will inaccurately name an unknown artefact, which shares perceptual properties and shape with a familiar artefact, with the wrong label. For example, if a child labels a round candle "ball" (Nelson, 1979). Those representing an ALA argument will suggest that this is because they are both spherical in shape and as such have extended the label ball onto a similarly shaped artefact.

Bloom (2000) suggests, that the problem when examining children with limited vocabularies is that we are not entirely sure what it is they are trying to convey. They could simply be production errors (Gelman et al., 1998), it could be interpreted as "this looks like a ball', or a question "is this a ball?" or a statement "this would make a good ball". As such, Bloom does not consider these investigations particularly informative, as the interpretation is both broad and subjective.

To overcome the nature of production issues and interpretation children were tested on categorisation comprehension. In a simple yes or no task participants were asked whether or not the novel exemplar was a 'blicket' or not? It is suggested that comprehension tasks are more representative of children's understanding as it does not require the child to produce the name and as such reduces the chance of a production error (Gelman et al., 1998).

Bloom also discusses these interpretive limitations with regards to methodologies using pictures or toy representations of artefacts and preferential looking tasks with younger participants. Deák, Ray and Pick (2002) suggest that research asking children to sort or label static artefacts or pictures of artefacts only tests children's ability to draw inferences about function from static, pictorial representations. Deák and Bauer (1996) also report that pre-schoolers rely on shape and colour information more for inferences about pictures than they do on artefacts. As such, research utilising pictures of artefacts is skewed towards shape. In light of this, it was important to ensure the artefacts were "real" rather than pictures, and exposure was dynamic. As such we used two of the objects from previous experiments: the four-way radiator key and the circular air vent cover.

Finally, recruiting five different aged groups (three year-olds, five year-olds, seven year-olds, 10 and 11 year-olds and adults) tested comprehensively whether or not there was a developmental change in the definitive features used in categorisation. Generally speaking, it appears to be understood that between the ages of five and seven years of age we start to see a greater reliance on functional information and that by 10 and 11 years old we see similar responses to that of adults (Hammer, Diesendruck & Catz, 2003). Three year-old responses, as mentioned, are currently inconsistent across the literature and as such we feel are the most unpredictable at this stage.

This Experiment

This experiment tested four groups of children (3-year-olds, 5-year-olds, 7-year-olds, 10- and 11-year-olds) and adults in order to examine whether categorisation definitions shift focus with age. All participants completed a warm-up session using familiar artefacts in order to help clarify the rules. The experimenter demonstrated a brush's use (action and function), and told the participants that Mr Rabbit liked to collect brushes. If they saw any brushes they should place them in Mr Rabbit's bucket. The experimenter then brought out the remaining four familiar artefacts, demonstrated their use, and asked the participants whether or not they were brushes, and where they should be put. The experimenter handed the artefact to participants for them to make their selection. If any participant had not completed this successfully they would have been excluded, however they all did.

This process was then repeated with the novel target artefact. It was named and children were shown its use twice. The 12 test trials when then presented with 12 further items (Table 4.6). These items varied in shape, and in the actions and functions made with them. There are two types of trial: six exclusion trials and six discrimination trials. In half of the exclusion trials, the item was an exact match for the target (same shape, same action, same function). In the other half the item was completely different (different shape, different action, different function). If participants understood the task they should correctly 'collect' all the items that were identical to the target, and reject the items that were different. As such these exclusion trials were used to determine whether a participant's data was sufficiently consistent to warrant analysis. The remaining six trials were the discrimination trials. These trials used items with different combinations of shape, action and function (Table 4.6). Depending on which items participants collected or rejected, these trials were used to determine whether participants were categorising by shape, action or function.

If children categorise using a specific feature, then they will make a within-category selection (put in Mr Rabbit's bucket) when the target and new item are the same for that feature, and a between-category selection when the target and new item are different. So for example, if children think that shape defines category membership, then they will think that a new item belongs to the same category as the target, when the new item is the same shape as the target. Likewise children will think that a new item belongs to a different category to the target, when the new item is a different shape from the target. In contrast, children's categorisations will be unaffected by whether or not the new item and target are associated with the same action or function.

Three alternative patterns of results can be predicted. Firstly an ALA would predict a strong shape bias in young children, such as the 3-year-old participants (e.g., Smith et al., 2002). Whereas, conceptual accounts such as SCA and the Design Stance would suggest that, even young children should demonstrate a function bias (Kemler Nelson et al., 1995, Kemler Nelson, 1999). Perhaps both theories would predict a more conservative shape and function approach at 5 years old and then a functional approach from aged 7 years and upwards. Finally, an embodied cognition approach would suggest that the youngest children should categorise according to the action demonstrated with the artefact.

4.3.2 Method

Participants

In total, data were collected from 24 adults and 127 children. Four groups of children participated, 3 year-olds, 5 year-olds, 7 year-olds and 10 and 11 year-olds. (For a detailed breakdown of participants please see Table 4.5). All children attended nurseries and schools in a greater London borough. As before, head teachers and class teaches gave consent and parents were given the chance to 'opt out'. Adults were recruited from a wide range of backgrounds and asked for the necessary consent before beginning. All participants were given the right to withdraw at any time.

Table 4.5: Experiment 9 – Breakdown of Age and Gender of Participants.

Measure	3 year-olds	5 year-olds	7 year-olds	10 & 11 year-olds	Adults
n	48	28	28	23	24
Mean years; months	3; 7	5; 2	7; 4	10; 11	31
Age range years; months	3; 0 – 3; 11	5; 0 – 5; 10	7; 1 – 7; 9	10; 0 – 11; 5	19 – 56
Gender (M / F)	18 / 30	13 / 15	14 /14	11 / 12	7 / 17

Design

The study used a within-participants design. Children and adults each completed 12 trials encompassing all the independent variable conditions manipulating the shape (same / different), action (same / different) and function (same / different) of a novel artefact; trial order was counterbalanced across participants. The dependent variable was categorization consistency. Children make a within category selection when the target and item are the same, and a between category selection when the target and item are different. Categorisation consistency refers to the regularity with which participants' select shape, action or function matches.

Materials

5 familiar artefacts were used: 3 small hairbrushes, a crayon and a pair of child safe scissors. In total, 26 novel artefacts were required, 13 examples of two different hand-sized novel artefacts- not all of the artefacts would be used for every participant. During the

testing phase, 19 artefacts were used per participant; 13 of one shape (seven as demonstrations and six during same shape trials) and six of the alternative shape (all during different shape trials). The use of these artefacts as the target shape was counterbalanced across participants. A ‘function box’ was used as a substrate to generate the appropriate functions by operating one of the two secret foot pedals (either turning on a light or making a buzzer sound). Additionally we required a large cuddly toy (Mr Rabbit) who liked to collect blickets, a bucket for him to collect them in, and a bag for the experimenter to collect the non-blickets items in.

Procedure

All the children were tested in a familiar environment, in a quiet corner of their classroom at school. Adults were also tested in a familiar environment, either in their workplace or at home. Each participant took part in a warm-up and testing sessions working individually with the experimenter and her helper Mr Rabbit (cuddly toy). Each session lasted approximately 10 – 15 minutes.

During the warm-up session children were introduced to the experimenter (E) and her friend Mr Rabbit and were told that Mr Rabbit liked to collect things. They were asked if they could help Mr Rabbit find the things he likes to collect. E told the children that Mr Rabbit likes to collect brushes and showed the children a small hairbrush with a demonstration of how it works (brushing Mr Rabbit’s fur – its action and function). After this demonstration, E showed the children the special bucket Mr Rabbit likes to keep his collection in, and placed the hairbrush in the collection bucket, out of sight. E then gave the children another 4 artefacts in turn, demonstrating their use (action and function), and asked the children to put the brushes in the box for Mr Rabbit and anything that wasn’t a brush back in the experimenter's bag (all out of sight). E noted where the familiar items were placed. These items were then removed from the table. If any children could not complete this task they would have been excluded from the remaining test, however, all children were successful during the warm up session.

The testing session followed a similar process. The children were told that Mr Rabbit also likes to collect blickets. E then showed them a novel artefact saying, "This is a blicket, look". E demonstrated the novel action and function and placed it in the bucket. Selecting another blicket, E repeats this for a second time, "Oh, Mr Rabbit does like blickets, look again"- once again demonstrating the novel action and function and placing the item in the bucket. The participants were then asked to help Mr Rabbit find the rest of the blickets, reminding them, "Remember, if it's a blicket, we put it in the bucket for Mr Rabbit. If it is not, then we put it in the bag." The experimenter then brings out a series of 12 items whose shape, action and function may either be the same or different from the original (see Table 4.6 for trial combinations)

For each trial, the children watch the demonstration, then are given the item and asked "Is this a blicket? Where shall we put it?" Routinely, the original demonstration of the blicket is repeated after every few items so as to remind the children what they are looking for. For the three, five and seven year-old participants the original demonstration was repeated after every two items. For the 10/11 year-old and adult participants the demonstration was repeated after 4 items. After each demonstration the experimenter reminded participants "This is a blicket, we put it in the bucket". Both the target artefacts and the order of trials were counterbalanced across all the participants. The experimenter records the child's response to categorising each novel artefact.

Table 4.6: Experiment 9 – Table Detailing Shape, Action and Functional Similarity of Test Items to the Target Artefact.

Trial	Shape	Action	Function
1	Same Shape	Same Action	Same Function
2	Different Shape	Same Action	Different Function
3	Same Shape	Different Action	Same Function
4	Different Shape	Different Action	Different Function
5	Same Shape	Same Action	Different Function
6	Different Shape	Different Action	Same Function
7	Same Shape	Same Action	Same Function
8	Different Shape	Different Action	Different Function
9	Same Shape	Different Action	Different Function
10	Same Shape	Same Action	Same Function
11	Different Shape	Different Action	Different Function
12	Different Shape	Same Action	Same Function

Trials marked in grey are exclusion trials – children were required to make accurate selections on these trials to be included for analyses. Trials marked in black are discrimination trials – these trials were analysed to establish categorisation consistency.

4.3.3 Results

Initially we examined the three completely identical and three completely opposite trials. For each participant we calculated a score out of six. Each participant scored one for every time they correctly selected an exact target match (same shape, same action and same function) or successfully rejected the completely different artefacts (different shape, different action and different function). Participants were permitted to make one error. Naturally had participants been focusing on shape, action or function information to make their judgements it would follow that three exact matches were blickets and thus included. Similarly, they should reject the three opposite artefacts. If any participants scored fewer than five out of six, it was concluded that they were not using shape, action or function as criteria for categorisation and thus they were excluded from the remaining analysis. Following this criteria, 19 3-year-olds, two 5-year-olds, one 7-year-old and one adult were excluded from further analysis.

For the participants scoring five and above on the analysis of the initial six trials, scores were calculated for their shape, action and function responses. Every time a shape-matching item was put in the bucket, shape identical scored one. Every time the participant rejected an item that was a different shape, shape opposite scored a point. This was repeated for every information type, for every participant to generate a means score.

Of the 6 remaining trials we had three shape matches, three action matches and three function matches as seen in Table 4.6 (items in grey have already been analysed and excluded). Working through an example, for a participant who uses shape to differentiate their categories they will place same shape artefacts three, five and nine in the bucket. Artefacts two, six and 12, with different shapes, are rejected and placed in the bag. For each of the same shape artefacts placed in the bucket, shape identical scores one. If all three same shape items are placed in the bucket shape identical (SI) scores a total of three. Looking at the remaining items that have been included, as well as just a shape match, there is one shape and action match (number five) and one shape and function match (number three). As they have both been included as within category items, action identical (AI) scores one and function identical (FI) scores one.

Looking at the artefacts that were rejected we can see we have three that are different shapes so shape opposite (SO) scores a total of three. One artefact that's a different shape and different function (number two) so function opposite (FO) scores one and one item that is a different shape and different action (number six) so action opposite

(AO) also scores one. Total shape (S), action (A) and function (F) scores are then calculated by adding identical and opposite results together. A data entry example of a shape-matching participant is shown below (Figure 4.1).

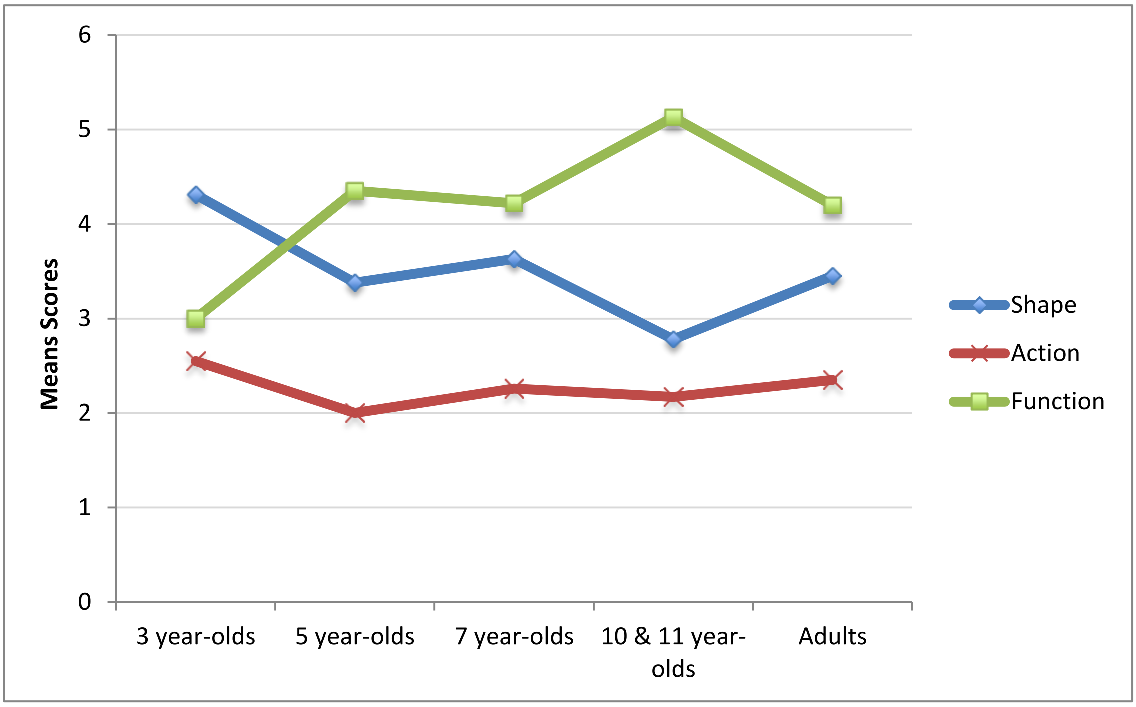
Figure 4.1: Experiment 9 – Sample of Data Entry for Participant 4.

ID	Age in Months	Sex	SI	AI	FI	SO	AO	FO	S	A	F
4	39	M	3	1	1	3	1	1	6	2	2

Information type means were then calculated and compared for each age group. For either shape, action or function a score of three suggested that children were relying on this information type no more often that one would expect by chance. A score of above three for any of the information types suggested the group were using that information as criteria for categorising. A score of below three might suggest participants were actively avoiding that information type. The means for age group and information type are displayed below. By examining the means in Figure 4.2, we begin see how each of the age groups categorized the novel artefacts.

At first glance it appears that the 3 year-olds categorised using shape, function information scored at chance levels. The five and seven year-olds had a small reliance on shape but mainly used function information. The 10 and 11 year-olds and adults did not use shape information at all to categorise. Both groups relied solely on function information. Despite what we thought we might find based on the previous chapters' data, none of the groups, not even the youngest participants, categorised the novel artefacts based on their action. If anything it appears as if all of the age groups ignored action information when defining their novel categories.

Figure 4.2: Experiment 9 – Graph to Show Information Type Means Scored Across Age Groups.



A 3 (information type: Shape, Action and Function) x 5 (group: 3, 5, 7, 10 – 11 year-olds and Adults) repeated-measures ANOVA was performed to examine categorisation consistency. Analysis yielded a significant main effect for information type, (2, 123) = 41.736, p < .001. Bonferroni post hoc comparisons indicated that all levels were significantly different; participants categorised using function more often the shape (p = .008) and action (p < .001) and shape more often than action (p < .001). The main effect for group was not significant but approaching it, *F* (4, 123) = 2.228, p = .070. However, the two-way interaction between information type and group was significant, *F* (8, 123) = 5.100, p < .001.

Exploring the interaction, further t-tests examined significance across each the different conditions and groups. Firstly one-sample t-tests established differences between information types from chance (with chance set at 3). On the whole, both shape and function were used to categorise significantly more often that one would expect from chance performance: Shape (M = 3.45, SD = 1.711), t (127) = 2.997, p = .003 and Function (M = 4.20, SD = 1.740), t (127) = 7.821, p < .001. Perhaps most surprisingly, action results show participants used action information to categorise significantly *less* often than one would expect to see by chance (M = 2.35, SD = 0.716), t (127) = -10.240, p < .001.

Table 4.7: Experiment 9 – One Sample t-test Results Across Information Type and Age Group.

Information Type	Measure	3 year-olds	5 year-olds	7 year-olds	10 & 11 year-olds	Adults
Shape	n	29	26	27	23	23
	Mean	4.31	3.38	3.63	2.78	2.91
	Std. Dev.	1.63	1.94	1.78	1.48	1.24
	t-test	4.335**	1.011	1.839	-0.706	-0.336
Action	n	29	26	27	23	23
	Mean	2.55	2.00	2.26	2.17	2.78
	Std. Dev.	0.91	0.00+	0.53	0.65	0.85
	t-test	-2.654*	-	-7.322**	-6.092**	-1.226
Function	n	29	26	27	23	23
	Mean	3.00	4.35	4.22	5.13	4.61
	Std. Dev.	1.46	1.98	1.72	1.486	1.27
	t-test	0.000	3.469*	3.698**	6.874**	6.075**

One sample t-test results when chance is set at 3
* p < .05, ** p ≤ .001, + *t*-test cannot be computed when St. Dev. is 0

One-sample t-tests also examined which information types were used significantly most often for each age group. From Table 4.7 we can confirm estimations made when examining the means. This data demonstrate that children from 5 years old to adults successfully use function information to categorise novel artefacts. 3-year-old participants categorised using shape information. Interestingly, no groups relied on action information when categorising the novel artefacts.

These data support a developmental strengthening of functional understanding, this is reinforced by a positive correlation in the children's data between age in months and function means $r = 0.411$, $p < .001$ suggesting that as children get older they are more likely to categorise using functional information. Conversely, there was also a negative correlation between age in month and shape means ($r = -0.021$, $p < .05$) and age in months and action means ($r = -0.215$, $p < .05$). Naturally as children tend to rely on function information more heavily they are using shape and action information less.

4.3.4 Discussion

This experiment aimed to provide an unbiased insight into the development of novel artefact categorisation for children aged 3-years-old and upward. Congruent with the literature, I directly compared information types of artefact shape and function but further added the component of artefact action to examine whether this would account for the discrepancies in previous research results. Moreover, studying such a broad age range allowed insight to any developmental patterns. Previous studies have focused on smaller age ranges; 3-year-olds (Smith, Jones & Landau, 1996), 3- to 6-year-olds (Kemler Nelson et al., 1995), 4- and 5-year-olds and adults (Diesendruck, Hammer & Catz, 2003), 4-year-olds, 6-year-olds and adults (Defeyter, Hearing & German, 2009).

Initially examining the role of action, both children and adults ignored action information when categorising novel artefacts (rejecting an embodied cognition approach to categorisation for these age groups). This is a little surprising considering the apparent advantage within the fast mapping results of the previous chapter. As you can see for the 3-, 7- and 10/11 year-old participants, action information was used to categorise information less often than you would expect to see from chance performance. Within the 5 year-old children, not a single participant favoured action information and as such returned a standard deviation of 0 meaning a t-test result couldn't be calculated. Adults' action results were non-significant, any action preference or avoidance was simply by chance.

Perhaps participants did not categorise by action because they were already too old, and had already outgrown this approach to categorisation. Certainly from a historic, Piagetian account, children outgrow this initial sensorimotor stage at approximately 2-years-old. Perone et al. (2008) saw action information effecting 6 – 7 month old infants understanding of artefacts. Perhaps categorisation of artefacts by action is something that only happens in early infancy.

When examining the results for each age group we can see a clear developmental shift in information preference, from focusing on shape to focusing on function. A general consensus across theoretical approaches suggests that children's conceptual understanding develops and strengthens between five and seven years of age (Defeyter & German, 2003). Furthermore, that this conceptual understanding allows adults to categorise novel artefacts using functional information (Diesendruck, Hammer & Catz, 2003). This is corroborated by these data, which showed a positive correlation between the use of functional information to categorise and age in months (and conversely a negative correlation regarding shape information).

However, 3-year-old children did NOT use functional information to categorise artefacts, instead relying on shape information (conflicting with a SCA of categorisation). This is consistent with many other shape versus function forced choice tasks. For example, Deák, Ray and Pick (2002) took a different, perhaps slightly more ecologically valid approach, to studying thus. Using a traditional forced choice methodology they used unusual but genuine artefacts. For example, a metal flour shifter, a metal beer jug, (same shape but different function) and a ricer/sifter (same function, different shape). Naturally, this meant that these artefacts were specifically designed for their purpose and as such did afford their function. Through a series of three experiments Deák, Ray & Pick (2002) manipulated the salience and instruction of function. Four year-olds without instruction would categorise by shape, however if a function rule was demonstrated they would happily switch their focus and attend to function. However 3-year-olds, even with reminders regarding function on every trial would still categorise shape first. As these and my data suggest, we are still clearly finding evidence of a shape bias in 3-year-olds as predicted by an ALA. However, what we cannot be sure of from one experiment is why?

A large number of 3 year-old participants were excluded (n = 19) for failing to demonstrate any obvious pattern of response. For example, had the children only excluded the three completely mismatching artefacts (different shape, different action and different function) and placed the other nine artefacts in the bucket then they could have been described as having a very liberal approach to categorising. Conversely had they only included the three items that perfectly matched the target (same shape, same action and same function) then they could have been described as very conservative. Either way children following this pattern of response would have scored 6/6 in the first analysis as having accepted the three exact matches and rejected the three opposites.

Seeing this number of children excluded perhaps suggests that the task was too complex and that the younger participants simply did not understand what was being asked of them. However, all children were successful with the familiar artefacts in the warm-up session. Furthermore, for some 3-year-olds this simply wasn't the case. 29 children did manage to understand the task and of those 29, 22 children scored a perfect 6/6 and with no errors, obviously demonstrated a discernible pattern of response (namely a shape bias). However, 16 of the 19 excluded 3-year-olds demonstrated an inclusion bias whereby they placed 10 or more items in the bucket. Perhaps these 16 were using different information to categorise the artefacts. One possible explanation for these responses is that children saw all the artefacts acted upon the same substrate.

During the procedure all the artefacts interacted with the same ‘function box’. When the artefact acted upon it, it either turned on a light or a buzzer. During the design stage I felt that this was acceptable as both were very distinctive functions. Previous methodological concerns have been that function had to be inferred, or that the function presented was not a *real* function (e.g. simply placing an item into a container- thus not achieving any real goal or substrate change). This was not the case here as both functions were realistic and separate. Moreover, during the warm up session, children saw two familiar artefacts both acting upon the same substrate. Participants saw both a crayon drawing on the paper and the scissors cutting it. I felt that this would demonstrate that two artefacts acting upon the same substrate was not unusual.

However, despite best efforts to cue the understanding of performing two functions on the same substrate, and the two functional outcomes being distinctly different, perhaps these 16 children included all of the items as within category exemplars as they all acted upon the same substrate. As a substrate is key to artefact function, perhaps this demonstrates young children are thinking about function, just not in the same way as adults.

4.4 General Discussion

Experiment 8 showed that in referent selection tests, requiring understanding of mutual exclusivity, 3- and 4-years-olds treated name, action and function equally. When children were faced with novel information and a familiar and novel artefact, children choose the novel artefact as the novel referent. I was able to reject a simple novelty bias as children in the familiar condition, when faced with the familiar name, action or function attributed to that artefact, rejected the novel referent. Thus while children understand that an artefact should not have two names, they will also only attribute one action and one function to an artefact. It appears that children understand that an artefact has a specific name, action and function, that these are all characteristic features of an artefact.

From here Experiment 9 examined which of these features children would identify as the definitive feature in a categorisation task. In a forced choice test – varying shape, action and function – children were asked which test item matched the novel target artefact. Despite the apparent advantage for action learning presented in the fast mapping data, I found no indication that children use action information to categorise novel artefacts. My results indicated that 3-year-olds typically categorised the artefacts based on their shape whereas children aged 5 to 11 years old (and adults) all categorised artefacts by their function.

It is possible that what we are seeing is not a developmental shift from shape to function categorisation, but a more subtle, strengthening of understanding. Ultimately, it's not that children think more about function as they get older; it's that the *way* in which they think about function changes. Consistent with this, research by Defeyter, Hearing and German (2009) established that children aged four to six *describe* an artefact's function differently to the way they name it and categorise it. This is important to recognise that the way children think about their artefact function knowledge may be applied differently in different tasks (Defeyter et al. 2009). Children were shown line drawings of two artefacts and told that “Jack made it for carrying goldfish” but “Sally uses it for carrying bottles”. In the first experiment children were asked what the item was for; or in other words what was the artefact’s function? Children were equally likely to select either the designer’s intended function or the current use function. As the object afforded either use, participants selected artefact use at random. In the second experiment children were shown the same artefact with the same description but asked what it was; in other words what is the artefact’s name? Children regularly labelled the object using the designer’s intentions – fish carrier.

Defeyter et al. (2009) state that “the results point to a dramatic dissociation between function judgement and categorisation” (p. 263). Information about an artefact’s designer was used when naming the artefact, but not when asked to make a functional decision about what it was for. In my research, what 3-year-olds may understand about artefacts having specific functions may be useful in a mutual exclusivity, referent selection task (Experiment 8), but not utilised in a categorisation task (Experiment 9). Although children understand something about artefact function, this has not yet been assimilated for use across all tasks/domains.

Recognising that function knowledge may not be utilised across all tasks highlights the complexities of function. As previously noted, function on the whole is largely conceptual; although we can observe an artefact in use and infer a function occurring, we have to understand a great deal to separate the function knowledge from an artefact demonstration. As adults we often understand a designer’s intention and object affordances in line with laws of mechanics or other scientific knowledge. When faced with a simple artefact, we can often use this knowledge to make sense of an artefact's function. Yet, as adults, we also use plenty of artefacts whose workings we do not understand (e.g., a smart phone), while still understanding their function(s) and being able to use them.

How can young children, with their limited understanding of the physical world, begin to make these links between intended design and mechanics, between form and function? Many of these questions are unanswerable with such limited research data but important to be considered. The embodied cognition approach suggests that children learn about the world through their interactions with it. Can these interactions begin to teach infants about basic mechanics, affordances and in turn function? For example toys that involve hitting something with a hammer may teach children about hammers needing a handle to hold and a flat head to make contact with other objects. Once the hammer hits it normally causes something, a part on the toy, to hide or make a sound thus creating substrate change. Certainly a shape-as-cue account of learning suggests that we understand the affordances of artefact perceptual features from a young age, but do not necessarily detail how we come to learn this information in the first place.

In summary, following referent selection tasks I observed 3-year-old children demonstrate mutually exclusive behaviour towards artefact name, action and function information. It appears that children aged three-years-old understand an artefact to have a specific name, action and function. Moreover, that these features are considered characteristic of the artefact category, thus relevant to all category exemplars. However, when placed in direct conflict to test which is considered the defining feature I found 3-year-olds demonstrated a shape bias, whereas children aged 5- to 11-years-old categorised more similarly to the adults, attending to function.

Chapter 5

General Discussion

5.1 Summary of the Present Findings

This thesis has investigated young children's ability to learn the names, actions, and functions associated with artefacts. Chapter 2 investigated referent selection and fast mapping of artefact names and actions. Chapter 3 focused on learning of artefact information in a real world context, developing a fast mapping approach to learning artefact names, actions and functions. Chapter 4 investigated what children understand about these information types with regards to their contribution to artefact categories.

Experiment 1

It has been widely documented that children will not attach a novel name to a previously named category (e.g., Markman, 1990; Golinkoff, Mervis & Hirsh-Pasek, 1994). Experiment 1 used a referent selection to task to investigate this phenomenon, directly comparing artefact names with artefact actions. Four and 5-year-old children were presented with a novel and a familiar artefact and asked either "Pass me the koba" or to "Pass me the one we do this with [pantomiming novel action]". The majority of participants selected the novel artefact in both naming and action conditions. As no significant difference was found between the two conditions, these data suggest that children are equally likely to use a novel action to select a novel artefact as they are a novel name.

The principle of not attaching two names to one artefact is often referred to as mutual exclusivity (Markman, 1990). Previously, no one had tested whether mutual exclusivity is applied to actions in a referent selection task. Results from Experiment 1 *suggest* that, in a referent selection task, if one already knows the action associated with the familiar artefact then, the novel action must belong to the novel artefact. Unfortunately, from these data alone I could not conclude that mutual exclusivity is applied to actions. I did not compare children's reaction to *familiar* names and actions, as such I could not exclude the possibility that children simply prefer novel artefacts (this possibility was tested in Experiment 8).

Experiments 2 and 3

Following the original methodology of Carey and Bartlett (1978), I defined fast mapping as having three essential features: it involves incidental learning through minimal exposure, and leads to long-term retention. Using these criteria, I developed a fast mapping methodology to directly compare novel artefact name and action learning. In Experiment 2, following a brief, incidental exposure, participants were tested after a 5 to 7 day delay on name or action comprehension using an extension task. This task tested whether they would select an item that was the same shape, but different size and colour from the target). The majority of children did select the shape-matched item. These data demonstrated that not only can young children fast map novel actions, but also they can extend this information onto new exemplars of the target artefact's category after a long-term delay.

Experiment 3 examined the specificity of the action mapping to see whether children had correctly retained the exact action demonstrated at exposure. Children were allocated to either the novel action or second novel action condition; the exposure session was the same as Experiment 2, but at test children in the second action condition were shown a different novel action. Children in the novel action condition replicated the results of Experiment 2, correctly selecting the target artefact. In the second novel action condition the majority rejected the target, selecting an alternative item as the referent for the second novel action. These data suggest that children are retaining an accurate sensorimotor representation of the novel action.

As there has been no stringent examination of artefact action fast mapping, these data are novel. I have found that children aged 3-years-old, following brief, incidental exposure, can retain novel artefact-action mappings up to seven days later. Moreover, there was no significant difference between my novel action and novel name condition suggesting that children are as capable of learning an artefact action via fast mapping, as they are its name.

Experiment 4

Experiment 4 developed a new fast mapping methodology, one in which a novel artefact use was demonstrated, in order to test learning of artefact name, action *and function*. Children completed a comprehension test either after a short distracter task in (immediate condition), or after 6 to 7 days (delay condition). In the naming condition they were asked, “Which one is the koba?”; in the action condition, “Which one do we do this with?” (pantomiming the novel action); and in the function condition they were asked, “Which one starts the music playing?” Results showed children successfully retained the artefact-name, artefact-action and artefact-function mapping after a one-week delay with no significant differences between conditions.

As with Experiments 1 to 3, no one has previously tested children’s artefact learning using a stringent fast mapping approach. Results suggest that children are equally able to learn an artefact’s function, after a brief incidental exposure, as they are name and action. Given that function knowledge must be *inferred* from the overall demonstration rather than directly observed (as with name and action), children’s ability to recall a fast mapped function is impressive. These data suggest that children are excellent learners of all knowledge needed for artefact use (name, action and function), and provide the most convincing evidence to date that children can fast map this information.

Experiments 5 and 6

With the results from Experiment 4 'at ceiling', I needed some poor performance in order to dissociate artefact name, action and function learning. Experiment 5 sought such poor performance, and focused on children's learning of function in the long term with two manipulations in: the number of demonstrations during the exposure session (one versus two); and the verbal labelling of the target artefact (labelling versus not labelling). Despite the more challenging exposure conditions, children were still able to retain the artefact-function mapping at levels significantly above chance. However, analysis demonstrated that retention was poorer with a single demonstration (as opposed to two), but was unaffected by whether or not the target was labelled. This information was used to design a more challenging test of fast mapping for the next experiment.

The procedure for Experiment 6 replicated Experiment 4, except children only observed one demonstration at exposure. To further test the methodology and findings, different materials were included to see if the results were generalisable to a different substrate, producing a different function (i.e., playing music versus opening a drawer). Children performed name, action or function comprehension tests after a 6 to 7 day delay. Results showed that only the artefact-action mapping was retained at levels above chance. No significant differences were found between the two different substrates: this suggests that findings may be generalisable across a range of functions. These data indicate that that children may find it easier to learn the actions associated with artefacts than their functions and names.

Experiment 7

Experiment 7 also utilised the methodology from Experiment 4, this time additionally comparing name and action *production*. As with previous experiments, no significant differences were found between immediate and delay conditions. *Comprehension* data replicated previous results (Experiments 2 to 4) with children consistently selecting the target artefact at ceiling levels, with no significant differences between name and action learning. However, a substantial difference was found between naming and action *production* even in the immediate condition. Only three children (19%) managed to reproduce the novel artefact's name in the immediate condition and none after a delay. Conversely, 75% produced the action after a one week delay. Following fast mapping exposure there was a distinct advantage for action production over name production, congruent with, but more striking than, previous production comparisons (e.g. Hahn & Gershkoff-Stowe, 2010).

Experiment 8

Experiment 8 examined two questions, firstly do children have a novelty bias or are they using the principle of mutual exclusivity in referent selection tasks with artefacts? Secondly, do children treat artefact names, actions and functions as characteristic features of artefact kinds? Improving on the procedure in Experiment 1, children were tested on both their response to familiar and novel artefact information. Results showed children displayed mutually exclusive behaviour with both familiar and unfamiliar information of all three types.

I was able to rule out a novelty bias, as children rejected the novel item when faced with familiar information. Furthermore, I concluded that 3-years-olds understand artefacts to be associated with a specific, name, action and function. The fact that children failed to attach a second action or function to a familiar artefact would suggest that, like name, children see these features as characteristic of that artefact.

Experiment 9

Experiment 9 aimed to investigate whether children will treat, shape, action or function as the defining feature of an artefact category. Although each may be *characteristic* of a category, which one is *necessary* to *define* category? No one had previously investigated action in the categorisation literature. Following results from Experiments 6 and 7, I wanted to examine whether, as action is best retained when learning about artefacts, would it continue to be regarded as the most important feature when young children categorise artefacts. Furthermore, I tested five different age groups in order to investigate the development of artefact categorisation.

Children were shown an artefact in use (with a distinctive shape, action and function) and told its name, 'blicket'. Participants, children (aged 3- to 11-years-old) and adults, were shown a series of items (varying in shape, action and function) and asked to decide whether or not they were also blickets. Three-year-olds tended to categorise artefacts based on shape; children from ages 5 years to adults relied more on function when categorising. Almost none of the participants used action to define their categories.

5.2 Implications And Contributions To The Literature

5.2.1 Fast Mapping of Artefact Information

I think that the fast mapping data presented in this thesis have contributed to the existing literature. Firstly, congruent with findings in Holland, Simpson and Riggs (2015), in my thesis I consistently applied three criteria, following the original fast mapping procedure of Carey and Bartlett (1978): incidental learning; minimal exposure to the novel information; and a demonstration of retention after a long-term delay. Reviewing other 'fast-mapping' research it is clear how few of them actually follow the procedure of Carey and Bartlett (notable examples include: Deák & Toney, 2013; Waxman & Booth, 2000; Jaswal & Markman, 2001; Spiegel & Halberda, 2011). Methodologies utilising overt exposure (Waxman & Booth, 2000) or explicit teaching (Deák & Toney, 2013) do not demonstrate fast mapping, just learning. While studies that do not require long-term retention (Jaswal and Markman, 2001: Spiegel & Halberda, 2011), do not demonstrate learning at all. In consequence, few studies that have truly investigated fast mapping (e.g., Vlach & Sandhofer, 2012; Holland, Simpson & Riggs, 2015), and none of these have investigated fast mapping of the actions or functions associated with artefacts.

Although there have been no previous fast mapping studies investigating artefact action and function learning, there have been a few articles that indicate rapid learning of these artefact features (Childers & Tomasello, 2002, 2003; Hahn & Gershkoff-Stowe, 2010; Casler & Kelemen, 2005). Data from Experiments 2 – 7 indicated that 3-year-olds were able to successfully retain novel artefact-name, artefact-action and artefact-function mapping for one week, following a brief, incidental exposure. As such, I believe that this research is an important contribution to the literature. It extends the work of Childers and Tomasello

(2002, 2003), Hahn and Gershkoff-Stowe (2010) and Casler and Kelemen (2005) to show just how able children are, when learning artefact information needed for use. Moreover, it demonstrates children are able to fast map more than just novel artefact names.

There has been some disagreement about whether fast mapping is a learning process specific to the acquisition of words (Waxman & Booth, 2000) or a more domain general learning process (Bloom & Markson, 2001). Previous research claimed to look at whether children can fast map *facts* about novel artefacts in direct comparison to fast mapping of artefact names (Waxman & Booth, 2000; Deák & Toney, 2013) however, neither of these studies meet my stringent fast mapping criteria. However, I suggest, in line with Childers and Tomasello (2002, 2003) that acquisition of facts is not the best test for whether a fast mapping approach is useful for more general learning.

Childers and Tomasello (2002, 2003) suggest that the most natural non-verbal information child learn about an artefact is its action. Therefore they suggest testing fast mapping of action (and function) in direct comparison with artefact names offers the best test of the language-specificity of fast mapping. Using comprehension tests (Experiments 2 – 4), I directly compared the fast mapping of a novel artefact's name, action and function. Children did not display any advantage in fast mapping the name over action or function. As there were no significant differences between these types of information, I conclude that fast mapping *is* a domain-general learning process (although not everything is fast mapped – Holland, Simpson & Riggs, 2015; Riggs et al., 2015). However, under more challenging learning conditions I did observe a dissociation in the fast mapping of name, action and function. Experiment 6 reduced the number of demonstrations of artefact information from two to one. Under these maximally stringent conditions, children only retained action information (name and function retention did not exceed chance). In addition to this, in

Experiment 7, when examining the production of name and action, children were only able to produce actions but not names. Thus I found that children learnt action best, not names (or functions).

Although Experiment 7 findings are congruent with previous name and action production research (Childers & Tomasello, 2002; Hahn & Gershkoff-Stowe, 2010) none had found such a large disparity between action and name production. I suggest that as previous research did not employ a stringent fast mapping methodology, their production results for words were improved through procedural memory supports such as repeated, ostensive naming. The harder the memory test, the more actions seem to stand out. This distinct advantage for action production is consistent with the proposal that seeing an action is like making an action (Simpson et al., 2013; Iacoboni et al., 1999). Thus when children observed the experimenter produce an action with the target artefact, this may have led to the creation of an output motor representation of that action. This motor representation can them be used by children in the action production task. If the same process does not occur with words (Simpson & Carroll, 2014), then a motor representation will not be available for the word production task.

Experiments 6 and 7 data also support an embodied cognition approach to learning about the world. Various researchers believe that children learn about artefacts through their physical interaction with them (Hahn & Gershkoff-Stowe, 2010; Perone, Madole, Ross-Sheehy, Carey & Oakes, 2008; Boncoddo, Dixon & Kelley, 2010). Action information is learnt before conceptual information. Although more research would be needed to investigate this, the fact that children were able to retain novel action information with greater accuracy than name or function information certainly supports a view of learning via action.

Regarding what information children will fast map, Childers and Tomasello (2002) suggest that children will rapidly learn information that is socially transmitted rather than stored in the world. They also state that "…fast mapping is not a process specific to language but is a process reserved for any information that will not be perceptually available at a later time" (Childers & Tomasello, 2002; p. 975). Childers and Tomasello (2002) and Riggs, Mather, Simpson and Hyde (2015) suggest that children will fast map and extend information that is relevant across category members. My data (Experiments 2 - 4) support *both* of these notions.

Children have consistently fast mapped artefacts' name, action and function demonstrating long-term retention. This information is relayed to children via observational learning, once the demonstration of name, action and function are complete there is no way of children reviewing this information unless someone repeats the demonstration. Moreover an artefact's name, action and function are consistent across category members. These data support these pragmatic explanations for fast mapping – children will fast map information that they can only observe infrequently and is relevant to more than one artefact.

Overall the fast mapping data in this thesis adds a great deal to the existing literature. Firstly, I suggest it is essential to be clear what conditions are necessary for learning to constitute fast mapping. Secondly, that fast mapping is not exclusive to word learning. It appears children will learn information that is not stored in the world (not visually based) and that are relevant across artefact categories. This includes a novel artefact's name, action and function. Finally, when faced with the most challenging learning environments, it appears that children find learning artefact action easier than learning name or function.

5.2.2 Mutual Exclusivity and Artefact Categorisation

The demonstration of mutually exclusive behaviour with artefact names is well established in the literature, although researchers offer different explanations for the behaviour (Heibeck & Markman, 1987; Markman & Wachtel, 1998; Golinkoff, Mervis & Hirsch-Pasek, 1994; Diesendruck & Markson, 2001). In contrast, much less research has investigated the mutual exclusivity with artefact actions and artefact functions (Birch, Vauthier & Bloom, 2008; Casler, 2014 – but not using referent selection task). In Experiment 8 I used a referent selection task to directly compare mutual exclusivity with artefact name, action and function and disprove the possibility of a novelty bias. I found that 3-year-old children demonstrated mutually exclusive behaviour regarding all information types. This suggests that children understand artefacts to be associated with a specific name, a specific action and a specific function.

No one had previously examined whether mutual exclusivity is applied to function using a referent selection task. However, my results contradict studies, which suggested that children do not apply the mutual exclusivity principle to function (Birch, Vauthier & Bloom, 2008; Casler 2014). However the tasks used in the previous research were much more complex. I suggest that the simplicity of the referent selection tasks makes it ideal for investigating mutual exclusivity.

Experiment 9 extended previous categorisation literature (e.g., Smith, Jones and Landau, 1996; Kemler Nelson 1999). This literature suggests that adults categorise novel artefacts by their functions (e.g., Diesendruck, Hammer & Catz, 2003). What is still in contention is how children categorise novel artefacts, and at what age their categorisation and understanding of artefacts becomes adult-like (Cantrell & Smith, 2013; Booth, 2014; Kelemen, Seston and Saint Georges, 2012). The literature suggests that young children are susceptible to a shape bias (Gentner, 1978; Landau, Smith & Jones, 1988). As discussed in Chapter 1 (sections 1.5.3 – 1.5.5 inclusively) there are two main schools of thought which try to explain this bias. The Attentional Learning Account (ALA) suggests that children attend to an artefact's shape as it cues artefact names, and therefore artefact categories (Smith et al., 2002). The Shape-as-Cue Account (SCA) suggests that children attend to shape, but that they do so not because it cues the artefact's name, but because it cues the artefact's function (Bloom, 2000). Thus according to SCA even young children categorise artefacts by function.

Experiment 9 aimed to investigate artefact categorisation for children aged 3-years-old to adult. Following the retention advantage for artefact action, I wanted to investigate whether it would continue to be regarded as the most important feature when young children categorise artefacts. Results suggest that 3-year-olds categorise artefacts by shape, while children aged five to 11 years and adults categorise using function. None of the age groups tested seemed to define artefact categories using action information. Thus, despite evidence that young children learn about an artefact's action first (Experiments 6 and 7), action was not used as a defining feature in artefact categorisation. After one experiment I am reluctant to state whether I support ALA or SCA. However, my youngest children did attend to shape over function. One would imagine that ALA researchers would claim that this is because they attend to shape as cue for an artefact's name and category. These children seemed not to use function, even though this information was clearly provided, and older children did make use of it. Nevertheless I would wish to replicate these findings with different functions, and using different tests of categorisation, before drawing firm conclusions.

Overall, the mutual exclusivity research reported here suggests that children aged three years understand an artefact to have a specific name, specific action and specific function. As such they will not attach novel information to familiar referents for which this information is already known. The categorisation research suggests that 3-year-olds do not yet categorise artefacts in an adult-like fashion. The youngest children in this experiment used shape as the defining feature for categorising novel artefacts; older children and adults use function, and no age group uses action.

5.3 The Future of Research Into the Fast Mapping and Categorisation of Artefact Knowledge

All of the evidence provided in this thesis suggests children are excellent learners of artefact knowledge for use. However, as very little research has been done in this area, beyond my own, there is still plenty to investigate, and findings always need to be replicated. With inconsistent retention results among previous fast mapping literature (Horst & Samuelson, 2008; Vlach & Sandhofer 2012), it is vital to replicate results shown here. Such follow-up research may also help to clarify inconsistencies in previous research. Regarding future replication, it would also be beneficial to establish whether these findings are generalisable to other artefacts, actions, substrates and functions. As was briefly touched upon in Experiment 6, it appears that my fast mapping data were the same using two different functions and substrates.

With ceiling results in Experiment 4 – good comprehension of artefact-name, -action and -function mappings after a week – it would be interesting to investigate the fidelity and extent of these artefact mappings further. Firstly, by checking that artefact-information mappings are still recalled after a one-month delay (as in Carey & Bartlett, 1978, and Heibeck and Markman, 1987) as this has not been replicated in more recent research (e.g., with words in Vlach & Sandhofer, 2012). Moreover, will good comprehension also be observed with younger participants? A similar test with 2-year-olds may reveal when these fast mapping abilities develop. With the results from Experiments 6 and 7 revealing an advantage for learning artefact action, would we find that younger participants fast map novel artefact action more easily than its name or function?

In Experiment 7, the name production results were strikingly poor. Within the current methodology children in the immediate condition were tested after a short distracter task (approximately two – three minutes after exposure). Even after this very short delay only 3 of 16 children reproduced the artefact's name. It would be worth repeating the procedure and testing immediately after exposure to see whether we find children are able to produce the name just after hearing it. If not it would suggest that their problem is with encoding rather than memory.

As mentioned in Chapter 4, it would be beneficial to clarify whether fast mapping of function is also extendable and specific. This may be useful in helping to resolve discrepancies between my own mutual exclusivity of function findings with those of Casler (2014) and Birch et al. (2008). Both of these articles report complex methods that resulted in no mutual exclusivity of function. Potentially, one could run a version of the procedure outlined in Experiment 4, but test artefact function extension and specificity (as I did for action information in Experiments 2 and 3). Will children reject the target, and instead select a different novel artefact for the second novel function as they did with function?

Experiment 9 results suggested that 3-year-olds defined novel artefact categories by their shape. However 19 participants had to be excluded from the analysis for various reasons (e.g., they accepted test items that were completely different from the target artefact). I suggested that some of these children may have been unduly attending to the substrate in the task. Even the test items that were completely different from the target still acted on the same substrate as the target. As such, it would be interesting to run a similar study where the different artefacts acted upon different substrates to remove this possible bias. Moreover, in a bid to clarify whether young children will define artefact categories according to an ALA or a SCA, it would be interesting to perform a study using carefully designed novel artefacts that afford their plausible function – closer to real world artefacts and judgements. Hopefully a clear, unbiased study (avoiding pitfalls of previous research) would further clarify whether 3-year-olds utilise functional information and affordances when categorising.

5.4 Conclusion

The data from this thesis indicate that that by three years of age, children have an understanding that each artefact category is associated with a specific name, specific action and specific function. Young children will fast map this socially transmitted, category relevant information after brief, incidental exposure, and can retain these artefact mappings when tested after a one-week delay. Young children appear to be particularly effective learning of the actions made with artefacts. However, despite these impressive (potentially adult-like) learning abilities, young children do not appear to take an adult-like approach to categorising artefacts. This may change with time – with focus passing from shape to function.

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