How are inhibitory demands created and avoided in developmental tasks?

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Abstract

This thesis investigates the creation and avoidance of inhibitory demands in inhibitory tasks. Chapter Two investigated whether inhibitory demands are lower in Stimulus Response Compatibility tasks when resisting verbal imitation than when resisting manual imitation. Preschool children took part in three experiments. Experiment 1 results were inconclusive. Experiment 2a and 2b results suggested word imitation (e.g., hear 'dog', say 'cup') is easier to inhibit than manual imitation (e.g. see |finger|, make a |fist|). Experiment 2b results support a Complexity account (Simpson et al., 2013; Simpson & Carroll, 2014): words' complexity leads to 'slow mapping' between speech perception and motor production. On hearing speech, motor representations are activated only a little or not at all: verbal imitation is not automatic.

Chapter Three investigates an alternative account of why verbal imitation is easy for young children to inhibit: Dissimilarity. It suggests that when words are phonologically dissimilar (e.g., 'dog' / 'cup'), verbal imitation is easy to resist. Experiments 3, 4 and 5 were consistent with this proposal. Experiments 4 and 5 also showed faster responding with dissimilar words. Taken together, results support a Dissimilarity account: it easier to inhibit word imitation when planning to say dissimilar words from those heard.

Chapter Four investigated why the Reverse Sort task (e.g., see |sun| card sort into |moon| card tray, see |moon| card sort into |sun| card tray') is easier than the Grass/Snow task (e.g., hear 'sun' point to |moon| card, hear 'moon' point to |sun| card) (see Peterson et al., 2016). Specifically, Experiments 6 and 7 investigated whether preschool children's use of an *IC*-

avoiding conceptualisation (Simpson & Carroll, 2018) enabled them to circumvent task rules. Under Conceptualisation, task rules conceptualised as *IC-avoiding* will reduce inhibitory demands – and improve performance. However, results did not support this proposal. Experiment 8 investigated whether slower responding in the Reverse Sort task reduces inhibitory demands. Results showed that children do respond slower in the Reverse Sort task, and were consistent with the proposal that slowing down responding reduces inhibitory demands.

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Dedication

To my Family

Ethics Statement

The author has obtained the necessary ethical approval required by the Dept. Of Psychology at the University of Essex in order to carry out the research contained in this thesis.

A copy of the approval documentation is available from the Dept. of Psychology offices at the University of Essex.

Chapter 1

Introduction: which factors determine the inhibitory demands of developmental tasks?

1.1 Introduction

Inhibitory Control (IC) refers to the cognitive ability to stop production of a dominant response in favour of another, subdominant response (see Diamond, 2013, for a review). In other words, IC suppresses inappropriate cognition. In order to be 'inappropriate', cognitions or representations need to be activated despite being incompatible with current goals. Where a representation is salient but inappropriate, IC is activated, and allows less salient but more appropriate representations to prevail.

Inhibitory Control is a key cognitive process that serves to explain some aspect or aspects of thinking and behaviour. Inhibition research has a long history: Breese (1899) and James (1890), for example, took part in early investigations. Inhibition has since been studied under a different name: 'negative priming' – the slowing down of response speeds and increased error rates following exposure to a to-be-ignored object (e.g. Tipper, 1985). More recently, studies have investigated Response Inhibition (i.e. the suppression of prepotent responses) which includes the ability to resist temptation and acting impulsively; Interference Control (i.e., selective attention); and Cognitive Control (i.e., the effective prevention of distracting representations in working memory). Whichever name is used, inhibition is argued to be one of three core components of Executive Function (Carlson, Zelazo & Faja, 2013) along with Working Memory and Attention. However, an alternative configuration of Executive Functions (e.g. Miyake et al., 2000) includes Task Switching which enables competent switching between goals. Together, these are the cognitive processes that enable humans to engage in flexible, goal-driven thinking and behaviour. Inhibition is needed to suppress activity inconsistent with goals. Working Memory maintains, updates and operates

individuals towards the successful completion of goals (e.g., remembering number strings and word lists). And Attention (Norman & Shallice, 1986) may be used to focus on a goal, direct eye gaze or sound location (see Morra, Panesi, Traverso & Usai, 2018, for further discussion of the distinctions between these concepts).

Simple Response Inhibition and Complex Response Inhibition are two families of task that measure Inhibitory Control (Garon, 2016). Simple Response Inhibition tasks require participants to suppress a dominant response. In one of the most well-known developmental examples of this type of task – the Delay of Gratification task (e.g. Mischel, 1974; Mischel & Mischel, 1983; Mischel & Metzner, 1962) - children must delay or withhold a prepotent response to eat a marshmallow. In contrast, Complex Response Inhibition tasks require participants to hold a dominant response in working memory *and* inhibit a prepotent response. In the Day-Night task (Gerstadt, Hong & Diamond, 1994), for example, 'day' and 'night' are considered to be prepotent responses. Therefore, to be successful on the Day-Night task children must say 'day' when shown a picture card containing a 'moon and stars', and say 'night' when shown a picture card containing a 'bright sun'.

1.1.1 Why should IC be studied in young children?

This section begins by providing three motives for studying IC in young children. (1) Its role in understanding goal-directed action; (2) its rapid improvement between the ages of 2-years-old and 5-years-old as shown in IC tasks; and (3) its relation to affective states, psychological disorder and life-long learning.

First, it is important to understand how IC facilitates and coordinates goal-directed action. The complexity inherent within the active computation of all environmental inputs through a finite cognitive system means that the system must be able to plan and execute tasks quickly, efficiently and sometimes automatically. According to Simpson and Carroll (2014) 'automatic' is best characterised as the inevitable activation of a motor representation following activation of a perceptual representation. In doing so, automatic task performance circumvents the limitations of a finite cognitive system. However, automatic responding may be problematic in some circumstances such as when it is inconsistent with task goals. Studying IC therefore allows researchers to better understand this set of processes.

Second, developmental tasks show large differences in IC as a function of age (see Peterson, Hoyniak, McQuillan, Bates and Staples, 2016, for a review). In children aged 2-years-old or less performance on Complex Response Inhibition tasks is poor. Between 2 to 5-years-old IC increases rapidly (Gerstadt et al., 1994; Jones, Rothbart & Posner, 2003; Peterson et al., 2016; Simpson & Riggs, 2005a). As a consequence, children in this age range are more able to resist prepotent responding. In children 5-years-old or older improvement in IC is modest (Urben, Van der Linder & Barisnikov, 2011). Given the observed differences in IC across these age ranges, and in particular the rapid improvement in IC between the ages of 2-years-old to 5-years-old, it is pertinent to understand how and why this change occurs so that a more refined understanding of IC can be ascertained.

Third, IC is found to be related to a number of cognitive capacities and processes, including: affective states (Carlson & Wang, 2007; Hudson & Jacques 2014); health (Moffitt et al., 2011), academic success (Neubauer, Gawrilow & Hasselhorn, 2012); ADHD (Senderecka, Grabowska,

Szewczyk, Gerc & Chymlak, 2012; Schachar & Logan, 1990); Autism Spectrum Disorders (ASD) (Chmielewski & Beste, 2015) - as well as other important skills such as problem solving (Senn, Epsy and Kaufmann., 2004). The tight relation between them is argued to be a function of an increase in inhibitory skills (Brocki & Bohlin, 2004). Carlson, Mandell & Williams (2004), for example, found inhibitory skills at 24-months-old predicted theory of mind success at 39-months-old. Given the existence of such a close relationship between IC and a multitude of psychological processes, it is necessary to understand how IC develops and how it influences - and is influenced by - these processes.

1.1.2. What does this introduction cover?

In the following sections I consider how it may be possible to create and avoid inhibitory demands in inhibitory tasks. The first part of the introduction begins by discussing the division of inhibitory tasks into two categories: Response-Given and Open tasks. I follow with a review of when IC develops, and children's capabilities in resisting prepotent responding in Response-Given tasks. I then define Response-Given tasks as either Stimulus Response Compatibility (SRC), Go/No-go or Delay tasks and consider evidence that suggests these tasks are inhibitory. Stimulus Response Compatibility (SRC) tasks require participants to resist inappropriate, prepotent responding. Go/no-go tasks require participants to respond on Go trials and resist responding on no-go trials, rather than resist making a prepotent response on presentation of a stimulus (as per SRC tasks). Delay tasks require that a choice is made between receiving an immediate - but small - reward, or receiving a delayed - but larger - reward. I also discuss the conditions that create the inhibitory demands of Response-Given tasks and argue *intention*, as the basis of inhibitory demands in SRC tasks, is reliant on three conditions: (1) stimulus-response association (2) task rule structure, and (3) rule application.

I then discuss how inhibitory demands of Response-Given tasks may be limited by delay and task conceptualisation. In the second part of this introduction I discuss Open tasks, and consider the conditions that create, and manipulations that reduce, their inhibitory demands. I then go on to discuss how inhibitory demands may be limited in these tasks using delay, response mode and conceptualisation.

1.2. The division of inhibitory tasks into Response-Given and Open Tasks.

I divide inhibitory tasks into two distinct types: Response-Given tasks and Open tasks (see Simpson, Simon & Riggs, 2004). In Response-Given tasks children are provided with response options and told how to respond. In contrast to Response-Given tasks, in Open tasks no response options are provided: children need to infer the response for themselves. Complex tasks and Simple tasks are two sub-types of Response-Given tasks. In Complex tasks children must select between alternative ways of responding, but not necessarily between alternative responses. For example, there is just a single response in Go/No-go tasks and children choose between making it (on go trials) and withholding it (on nogo trials). Simple tasks, on the other hand, typically require children to delay responding.

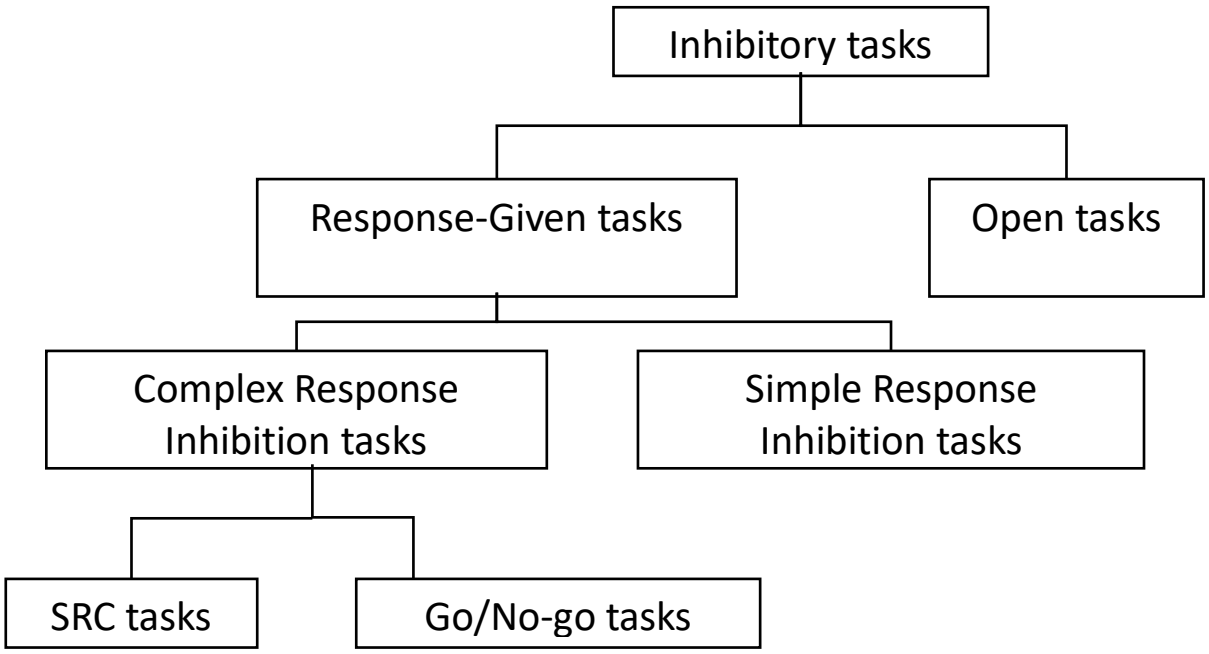


Figure 1.1. Basic classification of Inhibitory tasks that measure inhibitory control.

1.2.1 Response-Given Tasks

In Response-Given tasks children are provided with at least two ways of responding and are told how to respond. In most Response-Given tasks, the provision of two responses ensures children know prepotent responses are to be suppressed and a conflicting response provided instead. Prepotent responses are responses that are initiated automatically when a stimulus is presented. In the Day-Night task, for example, children are shown two picture cards: one with an image of a 'bright sun', the other with an image of a 'moon and stars' (Gerstadt et al., 1994; Simpson & Riggs, 2011). They are instructed to say 'day' when shown the 'moon and stars' card, and 'night' when shown the 'bright sun' card. In the Day-Night task, it is children's intention to make a response makes that response prepotent. In this task, then, responding 'day' to an image of the sun and 'night' to an image of the moon are considered prepotent (Gerstadt et al., 1994). Children aged 3-years-old often fail the Day-Night task: they say 'day' to an image of the sun, and 'night' to an image of the moon. An inhibitory perspective

assumes the difficulty young children face with this task is a function of weak IC. As a result, they are unable to successfully suppress prepotent responding. Inhibiting a prepotent response on Response-Given tasks in favour of a conflicting, inappropriate response arguably demonstrates effective IC. Response-Given tasks, such as the Day-Night task (Gerstadt et al., 1994), are argued to be reliable measures of IC (Montgomery & Koeltzow, 2010). It is suggested that the high internal validity and ease of administering Response-Given tests allows researchers to use these tasks to better understand the development of IC, as well as the creation and avoidance of inhibitory demands.

1.2.2 Open Tasks

In comparison to the structured format of Response-Given tasks, in which children may choose between defined responses, Open tasks require children to decide for themselves their own response. In Counterfactual Reasoning tasks (e.g. Riggs, Peterson, Robinson, & Mitchell, 1998) children are not explicitly told what type of response to make: they must infer a response as a function of the tasks' instructions. In their investigation of realist errors on counterfactual reasoning tasks, for example, Riggs et al. (1998 - Experiment 1) used two Open tasks: the Post Office task and the Chocolate task. The 'Post Office' story concerned two puppets, Sally and Peter. In the story, Peter wasn't feeling well and went to bed and Sally went to the shop to buy medicine. Whilst Sally was at the shop a phone call from the Postmaster summoned Peter to help put out a fire at the Post Office. Peter got out of bed and went to help. Having been told that Sally had finished her shopping, the children were then asked whether 'had there been no fire, where would Peter be?' (counterfactual question) and 'Where does Sally think Peter is?' (false belief question).

An Open task structure means children need to infer the response for themselves. As a consequence of children's ability to choose their own response from a pool of many, rather than choosing between only two options, in Open tasks no response becomes prepotent because children plan to make it. Relatedly, as a function of their similarity to real world situations in which children must reason about responses, Open tasks such as the Counterfactual Reasoning task (Riggs, Peterson, Robinson, & Mitchell, 1998) and Strategic Reasoning tasks (Apperly & Carroll, 2009) are considered to have high external validity.

1.3 When does IC develop?

Response-Given SRC tasks, including: Bear/Dragon (Reed, Pien & Rothbart, 1984), Hand Game (Hughes, 1996; Simpson & Carroll, 2014), Shape Stroop (Kochanska et al. 1997), Peg Tapping (Diamond & Taylor, 1996) and Grass/Snow (Simpson & Riggs, 2009), are typically used to chart development of young children's IC. The implicit assumption is that the inability to inhibit a prepotent response makes these tasks hard for children. Arguably, however, the most well-known preschool Response-Given SRC task is the Day-Night task (Gerstadt et al., 1994). To be successful on the Day-Night task children must say 'day' when presented with a 'moon and stars' card, and say 'night' when presented with a 'bright sun' card. Initial studies using the Day-Night task (Gerstadt et al., 1994) showed three-year-old's accuracy was poor – children can't resist producing a prepotent response - a result also observed by Simpson & Riggs (2005a), and in other Response-Given SRC tasks (e.g. Peg Tapping – Diamond & Taylor, 1996).

In their review of the Day-Night task, Montgomery and Koeltzow (2010) examined the development of inhibition. They showed the task has essential qualities, task performance and processes that underlie performance. In terms of task qualities, the Day-Night task has

reliability and convergent validity regardless of the task variant e.g. manual response (Carlson & Moses, 2001); colours and concrete nouns (Simpson and Riggs 2005a); or four response (Livesey et al., 2006). Furthermore, they assert sociodemographic, gender and SES differences are rarely linked to task performance, although cultural differences may lead to better performance for Asian children than Western children. And, in relation to the processes that underlie performance, Montgomery and Koeltzow (2010) conclude working memory does not fully explain children's success on the Day-Night task. Relatedly, differences between Day-Night task (a Complex task) performance and, say, the Delay of Gratification task (a Simple task) may be a function of the paired stimuli and response used in the former task generating response-set effects. Response-Set Effects are a function of the specific response's children plan to make (Simpson & Riggs, 2005b). Tasks that include Same-Set response sets are difficult for young children. However, Montgomery and Koeltzow (2010) also note performance may be improved by introducing delays between stimuli and responding (e.g. Diamond, Kirkham & Amso., 2002), or by removal of the response-set effect (Simpson and Riggs, 2005b).

More recently, Peterson et al. (2016) meta-analysed 198 Complex Response Inhibition studies to examine the development of inhibition through childhood and estimate age ranges of usefulness for IC tasks. Inhibitory control has "heterotypic continuity": its purpose through development remains similar, but its behavioural manifestation changes over time (Peterson et al., 2016). Interestingly, Perceptual inhibition, measured by tasks such as Baby Stroop and Spatial Conflict, starts to develop at around 2-years-old – an earlier age than with most Complex tasks. However, Association inhibition, measured by the Day-Night, Grass/Snow and Hand Game, for example, develops later at around 3-years-old. In terms of these inhibitory tasks, performance is also often subject to ceiling and floor effects: they are either too easy

or too difficult. Consistent with other research (Diamond & Taylor, 1996; Simpson & Riggs, 2005a), Peterson et al. show performance on Complex Response Inhibition tasks at 3-years-old is relatively poor - despite these IC tasks falling within the suggested useful and appropriate age range. Finally, but perhaps unsurprisingly, the dynamic development of inhibition during early years means that inhibitory tasks have a short window of usefulness, on average just two and a half years.

Whereas at 2-years-old IC is starting to develop (see Peterson et al., 2016, for a review) and at that age they may find some tasks difficult, children aged around 4-years-old perform much better. Using a Go/no-go task, for example, Wiebe Sheffield & Epsy (2012) showed that at 3.75-years-old children were more accurate and responded more slowly than younger children aged 3.0-years-old – suggesting improvements in older children's strategic deployment of IC. The meta-analysis of IC tasks compiled by Peterson et al. (2016) also documents sharp improvement in IC at around 4-years-old. Performance on what Peterson et al. (2016) term 'middle' IC measures, including: Day-Night (Gerstadt et al., 1994), Hand Game (Hughes, 1996), Reverse Categorisation (Carlson, Mandell and Williams (2004), Grass/Snow (Simpson & Riggs, 2009) and Knock-Tap (Allan & Lonigan, 2014) also show sharp improvement in accuracy between 2-years-old to 5-years-old, with the Hand Game and Grass/Snow tasks showing the sharpest improvement in performance from around 4-years-old.

Interestingly, the rapid improvement of IC observed during 2-years-old to 5-years-old is not sustained during later years. IC has been shown to only modestly improve between 5-years-old to 9- or 10-years-old (Urben, Van der Linder & Barisnikov, 2011), and shows only gradual

improvement thereafter into adolescence (Fjella et al., 2012). This suggests IC development may not be tightly linked to age after the 2-years-old to 5-years-old period of rapid development (for a short review of improvement in inhibition through development see Best & Miller, 2010). In their narrative review, Montgomery and Koeltzow (2010) summarised data from 21 IC studies and found only 12 showed a correlation between IC and age. However, this result may be better explained as a function of the differing ages of the children used in the sample group rather than in terms of a lack of correlation between IC and age: not all tasks included in this sample consisted of children of the same age. In 12 tasks younger children (aged 3.5-years-old or less) formed the sample group, whereas in the other 9 tasks older children (aged 3.5-years-old or greater) were used. In the younger children group the correlation between IC and age was 83%, and in the older group, only 22%. These results are therefore consistent with extant research: young children's IC is poor at 3-years-old, but improves rapidly thereafter (Diamond & Taylor, 1996; Diamond, 2002; Ikeda, Okuzumi & Kokubun, 2104; Jones, Rothbart, & Posner, 2003; Simpson & Riggs, 2005a; Simpson & Riggs, 2007).

SRC tasks are an effective and valuable resource for understanding the onset and development of IC in young children. SRC tasks vary in their methodology and may utilise one or both of two measures of success: Accuracy and/or Reaction Time. In Accuracy-based studies, children's total correct score obtained over a set number of trials is measured. Accuracy measures are common in IC task pre-tests (e.g. Gerstadt et al., 1994; Diamond & Taylor, 1996) and main test sessions (e.g. Calderon, Jambaque, Bonnet & Angeard, 2014). Pre-tests require children either to be accurate on a specific number of trials (Tregay, Gilmour & Charman, 2009), on consecutive trials (Roberts & Powell, 2005; Hughes 1998a), or on any

number of trials (Blair & Peters, 2003). In all studies, children who display good accuracy on first attempts at pre-test sessions progress to the main test session. Reaction Time studies measure elapsed time between the end of verbal stimulus presentation and onset of verbal response. They are typically used on older children as this age group has better IC than younger children - though not as good as adults. Older children's performance accuracy is likely to be at ceiling, or at least very good. Consequently, a more sensitive measure of performance is required.

In addition to differences in SRC task performance measurement, developmental literature shows SRC task procedures are also subject to differentiation. Practice trial quantity in tasks varies from 1 (Earhart & Roberts, 2014) to 15 (Perner, Kain & Barchfield, 2002), until competent (Allan, Allan, Lerner, Farrington & Lonigan, 2015; Flynn, 2007; Flynn, O'Malley & Wood, 2004) or until correct (Korucu, Selcuk & Harma, 2016). Test trial quantity also varies from 8 (Chasiotis, Kiessling, Hofer & Campos 2006; Chasiotis, Kiessling, Winter & Hofer, 2006) to 30 (Cheie, Veraksa, Zinchenko, Gorovaya & Visu-Petra, 2014). In terms of rule learning, whether rule reminders are used during pre-test (Diamond & Taylor, 1996), after a set number of trials during main test session (Hammond, Carendale, Bibok, Müller & Lieberman-Finestone, 2012), or not at all (Watson & Bell, 2013), are also common SRC task differences. Given these many variations, it's possible all or none of them influence performance (i.e. accuracy or reaction time) in some way. For example, when feedback *was* used in a Day-Night task Simpson & Riggs (2005a) showed accuracy increased by 15% - compared to the findings of Gerstadt et al. (1994). Given the variety and possible combination of SRC task procedures, which of these are best placed to reveal more about IC performance is under review.

1.4. Response-Given tasks

Response-Given tasks are defined by their structural characteristics as belonging to one of two task-type categories: Complex tasks (SRC and Go/no-go tasks) and Simple tasks (Delay tasks). SRC tasks (e.g. Diamond & Taylor, 1996; Gerstadt et al., 1994; Simpson & Carroll, 2014; Simpson & Riggs, 2005a) require participants to suppress an inappropriate response in favour of a conflicting response. Go/no-go tasks (e.g. Barker & Munakata, 2015; Simpson & Riggs, 2006; Simpson & Riggs, 2007) oblige children to respond or not respond based on the cue provided. Simple tasks (e.g. Diamond, Kirkham & Amso, 2002; Beck, Carroll, Brunsdon & Gryg, 2011; Simpson, Riggs, Beck, Gorniak, Wu, Abbott and Diamond, 2012) involve children deferring responding for a given amount of time.

Stimulus Response Compatibility (SRC) tasks comprise a family of IC-oriented developmental tasks. Typically, they require participants to resist inappropriate, prepotent responding. Prepotent responses are strong, automatically activated, responses. It is these responses that must be inhibited. For example, in the Day Night task children must resist the prepotent response to say ‘day’ to an image of the ‘sun’ or ‘night’ to the image of a ‘moon and stars’. The most widely known SRC task that requires the suppression of a prepotent response is arguably the Stroop Task (Stroop, 1935). It consists of colour words printed in incongruent colour ink (e.g. the word ‘red’ is printed in the colour green). Participants are instructed to state the colour of the ink the word is printed in (green) rather than the colour of the word itself (red). The Stroop task is difficult because the printed word ‘red’ interferes with naming of the ink colour ‘green’. This is because the word ‘red’ is initiated automatically when the stimulus is presented (see MacLeod, 1991, for a review). In other words, the printed colour is prepotent.

For obvious reasons, developmental researchers interested in IC are unable to use the standard Stroop task (Stroop, 1935); young children aged below 3-years-old lack the literacy skills to take part in this task. Even though they can comprehend a great many words by 3-years-old (Bloom, 2001), and would arguably know a wide range of colours by sight, their reading skills are virtually non-existent. Few 3-year-olds are capable of visually discriminating letters of the alphabet, let alone whole words. If children are unable to comprehend an element of the task, then, IC will not be tested (Simpson, Unpublished PhD thesis). Young children's inability to read therefore renders the standard Stroop task (Stroop, 1935) meaningless. As a result, age-appropriate SRC tasks, such as The Animal Stroop task (e.g. Wright, Waterman, Prescott, & Murdoch-Eaton, 2003) and Real Animal Size task (Catale & Meulmans, 2009; Ikeda, Okuzumi and Kokubun, 2012), are best employed when assessing young children's IC. In the Animal Stroop task (Wright, Waterman, Prescott, & Murdoch-Eaton, 2003) children are presented with an image of an animal with a contrasting head and body, for example, a rhinoceros' head and a horse's body. Naming the head is argued to be a prepotent response, and so to be successful at the Animal Stroop task children must inhibit providing this response in favour of naming the animal's body.

Go/no-go tasks differ to SRC tasks in that the former require participants to respond on Go trials and resist responding on no-go trials, rather than resist making a prepotent response on presentation of a stimulus (as per SRC tasks). Go/nogo tasks are difficult for young children due to children planning to make the go response on some trials. In doing so, the response may become prepotent on all trials. Similar to the standard Stroop task (Stroop, 1935), some versions of Go/no-go tasks are not applicable to young children: their inherent structure is too difficult. Stop-Signal tasks typically require children to stop an impending response when

an explicit signal is observed (e.g. Wessel & Aron, 2014). However, the complex format and a large number of trials arguably precludes most young children aged younger than 5-years from taking part: Carver, Livesey and Charles (2001), for example, had pre-schoolers take part in 216 trials. Fortunately, developmental researchers concerned with understanding IC in young children have developed alternative IC tasks that mirror the structure of adult-oriented Go/no-go versions, but without their associated difficulties. The 'Simon Says' task (Strommen, 1973) is one such example. In this task, children follow an experimenter's instruction on Go trials but not Nogo trials; importantly, the words 'Simon says' are placed before Go trials but not on Nogo trials.

Simple tasks are IC tasks in which children's ability to respond immediately is typically prevented or delayed, and includes: Delay of Gratification tasks (Wait) (e.g. Carlson, 2005; Mischel, 1974; Mischel & Mischel 1983), Delay of Gratification (Choice) (Garon, Longard, Bryson & Moore, 2012: Lemmon & Moore, 2007), Delay of Gratification (Temptation) (Kochanska, Murray, Jacques, Koenig & Vandegeest, 1996), and Don't paradigm (Kochanska & Aksan, 1995; Kochanska, Tjebkes & Forman, 1998) - although see Diamond (1990a) and Scerif, Cornish, Wilding, Driver & Karmiloff-Smith (2004) for Simple tasks that do not involve delay. However, of Simple tasks, Delay of Gratification tasks are the most well-known. This task requires that a choice is made between receiving an immediate - but small - reward, or receiving a delayed - but larger - reward. Used with adults and adolescents, a delay interval of 1-week has been used to assess for any relationship between delay of gratification and academic achievement and social adjustment (Wulfert, Block, Santan Ana, Rodriguez & Colsman, 2002). Used with younger children, however, the delay period is much shorter – around a minute or so. These types of Delay of Gratification tasks are useful for children aged

up to 5-years-old (e.g. Mischel, Shoda & Rodriguez, 1989) - although Wilson, Andrews and Shum (2017) show its usefulness can be extended to children aged 7-years-old when a modified task is used.

Three age-appropriate variations of the Delay of Gratification task are used with young children: Wait, Choice and Temptation (see Garon, 2016, for a review). The Delay of Gratification 'Wait' variant is arguably the most famous. Initially investigated in the 1960's to assess preference of delayed reward using a simple question and answer format (Mischel & Metzner, 1962), the 'Wait' variant has arguably since become synonymous with the 'Marshmallow test' (e.g. Mischel & Mischel, 1983; see Mischel, 2014 for a review). Briefly, in the marshmallow test children are sat in a room in front of a marshmallow and a bell and told they can win and eat two marshmallows, but only if they can wait until an experimenter returns to the room; alternatively, the child can win and eat the single marshmallow placed in front of them by ringing the bell before the experimenter returns. In this 'Wait' variant it is the child's ability to delay immediate responding, despite being literally faced with the reward, that is key to success.

The Delay of Gratification 'Choice' variant (e.g. Garon, Longard, Bryson & Moore, 2012) again requires children to choose between an immediate - but small - and delayed – but larger - reward – and as such is similar to the standard adult Delay of Gratification task. However, the 'Choice' variant differs from the 'Wait' variant in that it considers type (cards, sweets, toys) and quantity of the reward on offer as important in children's ability to delay responding. Interestingly, Garon (2016) identifies a U-shaped performance on 'Choice' tasks for children aged between 2-4-years-old: 2-year-olds and 4-year-olds perform well, 3-year-olds do not. As

a result of this unusual pattern of responding, Garon suggests 3-year-old's poor performance stems from their inability to successfully resolve conflict between desires of the current and future self.

Delay of Gratification 'Temptation' type tasks are exemplified by the Snack delay task and Gift Bow tasks (Kochanska et al., 1996; Kim, Nordling, Yoon, Boldt, & Kochanska., 2012). These types of tasks are similar to 'Wait' tasks in that children must delay responding until instructed by an experimenter. However, in 'Temptation' tasks the size of the reward does not increase due to delaying responding. For example, in the Snack delay task, children are told to wait to eat a chocolate snack; it is the length of time children must wait that varies from trial to trial whereas the amount of chocolate on offer remains the same.

Taken together, the results of inhibitory studies using Delay of Gratification tasks typically show children are more likely to fail as the delay continues. Moreover, performance on Delay tasks is closely commensurate with age: older children perform better on these tasks than do younger children.

1.4.1 What evidence suggests Response-Given tasks are inhibitory?

The structure of SRC tasks suggests children's performance on Response-Given tasks is a function of IC, rather than other components of Executive Function such as task shifting. Task shifting enables individuals to cognitively shift between one goal and another. Shifting is a requirement of tasks in which children must vary sorting by different dimensions. In the Dimensional Change Card Sort task (Zelazo & Frye, 1998; see Doebel & Zelazo, 2015 for a review), for example, picture cards are first sorted by shape before a rule change requires

children to then sort the same picture cards by colour. However, the structure of SRC tasks is such that they do not contain a switching element, so it is unlikely task shifting contributes to success on SRC tasks.

Working memory is needed to maintain, update and operate towards goals (e.g. Simpson & Riggs, 2005a). In SRC tasks, goals are task rules: children must respond using *if-A-then-B, if-B-then-A* rules. If children can't remember the rules then IC will not be tested; a failure of children's working memory to recall and apply the task's rule structure means they will forget to respond appropriately. However, when working memory is used effectively to apply the task's rules, IC needs also to be applied to resist prepotent responding. Thus, it is the recall and application of task rules in working memory that provide the basis for children responding in a specific manner, but it is the application of IC that determines success.

The strongest argument for IC as responsible for performance on SRC tasks comes from tasks in which working memory and IC demands have been separated. Preschool children perform well on control conditions of the Day-Night task (Gerstadt et al., 1994; Simpson & Riggs, 2005a), Hand Game (Simpson et al., 2006) and the Grass/Snow task (Simpson & Riggs, 2009). In Simpson & Riggs (2005a - Experiment 1), for example, children took part in a Day-Night task utilising two inhibitory conditions: a standard 'sun' / 'moon' condition and a modified black / white picture card condition, and a third – memory - condition consisting of abstract pictures. Whereas in all three conditions memory demands are similar, inhibitory demands are much lower in the memory condition than the standard or modified conditions because abstract pictures do not have well-established names (Simpson & Riggs, 2005a). Using these tasks Simpson & Riggs showed children aged 3.5-years-old had quicker reaction times and were

more accurate in the memory condition than the inhibitory conditions – suggesting IC underpins poor performance. That 5-year-olds performed better – they were quicker and more accurate – on inhibitory conditions than 3.5-year-olds suggests IC develops during this age range.

Taken together, results of IC tasks in which control conditions are used show children's difficulty is not a function of working memory demands. It is inhibitory demands associated with tasks that are problematic for children's performance. Standard Response-Given SRC tasks are hard because they require IC to be successful, and young children's IC is not sufficiently strong enough to enable them to overcome the inhibitory demands of the task.

1.4.2 What conditions create the inhibitory demands of Response-Given tasks?

I begin this section by asserting inhibitory demands of SRC tasks that use *if-A-then-b, if-B-then-A* rules are all created in the same way, despite nuanced differences in task structure between SRC tasks. Specifically, *intention* is a key source of inhibitory demands, and is a function of the tasks' inherent structure. If-*A-then-b, if-B-then-A* tasks use pairs of images as stimuli: for example, in the Day-Night task (Gerstadt et al., 1994) a 'bright sun' and a 'moon and stars'. By virtue of the stimuli set, the incorrect response 'night' is activated on presentation of the 'moon and stars' stimuli. Children's intention to make a response on an SRC task means it then becomes prepotent. Further, I argue *intention* - as the basis of inhibitory demands in SRC tasks - interacts with three SRC task conditions to create inappropriate prepotent responses: (1) inhibited responses are associated with the stimuli, (2) task rules consist of an '*if-stimulus-A-then-response-B, if-stimulus-B-then-response-A'* structure, and (3) participants must apply the *if-A-then-B, if-B-then-A* rules.

Condition 1: The to-be-inhibited responses are associated with the stimuli

Condition 1 presupposes inhibitory demands are a product of stimulus-response association. The assumption on the Day-Night task (Gerstadt et al., 1994) is that saying 'day' to a 'night' picture card is difficult due to the strong association between saying the word 'night' to a 'moon and stars' image. In this task the wrong response becomes activated each time a picture card is presented. Contrastingly, saying 'night' to an abstract picture card is easy because the abstract image stimulus and the response 'night' are not associated: the wrong response does not become activated each time an image is presented. Consistent with this hypothesis, developmental research shows SRC tasks in which stimuli and responses are not associated are comparably easier for children (e.g. Simpson & Riggs, 2005a; Simpson & Riggs, 2009).

A number of mechanisms have been suggested to account for how stimuli and responses become associated in SRC tasks: innateness, motivation or habitualness (Simpson & Riggs, 2007). The innate account suggests associations are simply a function of heredity: individuals are born predisposed to associate stimuli and responses. However, whilst this type of association may explain looking behaviours in very young children as innate and prepotent (Meltzoff & Prinz, 2002), arguably very few other associations are regarded as such. For example, very young children may often point to objects they desire, but this associated behaviour is not construed as being a function of innateness. The motivational account suggests associations are a product of the favourable consequences they produce. Arguably, however, the habitual account provides the most reasonable explanation of how stimuli and responses are associated; that is, associations between stimuli and responses occur through learning and experience. Stimuli and responses that are repeatedly paired with each other

lead to their association. For example, a child comes to associate an image of a dog with the noun 'dog'; in cognitive terms the stimulus – a dog – and the noun 'dog' become stored in the brain as a linked representation. Thereafter presenting the stimulus elicits the response. It is important to note, however, that habitualness itself is not sufficient in and of itself to make a response prepotent: additional factors must also be in place.

Condition 2: The task must have a 'if-stimulus-A-then-response-A/if-stimulus B-then-response-B' rule structure.

The *intention* to make a specific response in SRC tasks is an important factor in transforming habitual responses into prepotent responses (Diamond et al., 2002; Montgomery, Anderson, Uhl., 2008; Montgomery & Koeltzow, 2010; Simpson et al., 2012; Simpson & Riggs, 2005b; Simpson & Riggs, 2011). Research suggests responses become prepotent due to a Response-Set Effect (Simpson & Riggs, 2005b). According to Proctor (1978) a Response-Set is the sum of the stimuli and responses used in a task. Response-Sets may consist of either the same or different responses. Same-Set response sets use rules *if-stimulus-A-then-response-B, if-stimulus B-then-response-A.* For example, Diamond & Taylor (1996) had children tap twice with a rod when the experimenter tapped once, and tap once when the experimenter tapped twice. Different-set response sets use rules *if-stimulus-A-then-response-C, if-stimulus B-then-response-D.* For example, in Montgomery et al. (2008) children responded 'day' to a 'night' image and 'boy' to a 'girl' image. The Response-Set Effect refers to the finding that *if-A-then-B, if-B-then-A* (Same-Set) conditions are harder than *if-A-then-C, if-B-then-D* (Different-Set) conditions (Diamond et al., 2002; Montgomery et al., 2008; Simpson, 2005b; Simpson et al., 2012).

Response-Set Effects – children's difficulty in providing correct, but less salient, responses from within Same-Set stimuli - are a function of the specific response's children plan to make (Simpson & Riggs, 2005b). As a function of their rule structure, planned responses (e.g. the intention to make a response) in Same-set conditions lead to activation of a prepotent response each time a stimulus is presented. Same-Set conditions consist of an '*if-stimulus-A-then-response-B, if-stimulus-B-then-response A'* rule structure (e.g. hear 'sun' say 'moon' hear 'moon' say 'sun'). Consequently, Same-Set tasks have high inhibitory demands: prepotent responses are activated on presentation of the stimuli. In contrast, Different-Set conditions have low inhibitory demands: inappropriate responses are not activated by the stimuli and so do not become prepotent. Different-Set conditions consist of an '*if-stimulus-A-then-response-B, if-stimulus-C-then-response D'* rule structure (e.g. hear 'hand' say 'foot' hear 'dog' say 'cat'). Thus, if a task consists of an '*if-stimulus-A-then-response-B, if-stimulus-B-then-response A'* rule structure then it is this structure that will create its high inhibitory demands.

Condition 3: Participants must apply the 'if-A-then-b/if-B-then-a' rules.

Task conceptualisation relates to the process of turning SRC task instructions into mental representations of the rules. Inhibitory demands in SRC tasks are created by the If/then (*if-A-then-B, if-B-then-A*) rule structure. For example, in the Grass/Snow task children must point to the 'green' picture card when the experimenter says snow', and point to the 'white' card when the experimenter says 'grass'. The Grass/Snow task is difficult because the wrong response is triggered on each trial. Conceptualisation of rules in an if/then manner means that the *if-A-then-B, if-B-then-A* rule will be applied. As a consequence, the task will contain a goal-inappropriate prepotent response - and inhibitory demands - and will necessarily require children to employ their inhibitory control to be successful. However, one suggestion is that

if it is possible to conceptualise a task in a different way then inhibitory demands could be reduced (Simpson & Carroll, 2018). Response-Given tasks are designed to restrict the way children can think about the task – but there may be specific SRC tasks in which alternative *IC avoiding* conceptualisations are possible. In the next section I give examples of such SRC tasks – in which *IC avoiding* conceptualisations seem possible.

1.4.3 How are inhibitory demands of Response-Given tasks limited?

In the previous section I discussed how inhibitory demands in Response-Given tasks are created. In this section I discuss Delay and Task Conceptualisation and their contribution to inhibitory demand avoidance. Assessing how children may avoid inhibitory demands has practical benefits, for example, by providing them with the 'tools' to combat their weak IC in developmental tasks, and everyday situations that require them to regulate their behaviour. Further, assessing how inhibitory demands may be avoided has clear implications and advantages for theories of IC processing and knowledge of its development across early years.

Delay

Better performance has been observed in several inhibitory tasks when the task is manipulated so that children's responding is delayed. Three theories aim to explain how delay improves performance on SRC and Go/nogo tasks: Active Computation (Diamond, Kirkham & Amso, 2002), Passive Dissipation (Simpson et al., 2012; Simpson & Riggs, 2007) and Goal Reminder (Barker & Munakata, 2015). Active Computation and Passive Dissipation accounts each propose delay is intrinsically related to improved performance because it reduces the inhibitory demands of these tasks. Furthermore, these two accounts are not incompatible (Simpson & Carroll, in press) in that each of these processes may work

separately in the same task to reduce inhibitory demands. In contrast, the Goal Reminder account suggests improved performance is a function of 'task reminders' that are coincidentally incorporated when responding is slowed. That is, the task manipulation used to create the delay encourages children to reflect on the task rules.

Active Computation (Diamond, Kirkham & Amso, 2002) argues a delay between stimulus presentation and response enables children to think about the rules of the task (e.g. *if-A-then-B, if-B-then-A)* and implement them into their responding behaviour. In other words, delay provides additional time during which children can reflect on the rules and compute the correct response. In their (2002) study, Diamond, Kirkham and Amso used a Day-Night task to investigate the effects of delay on SRC task performance in children aged 4-years-old. They predicted that in a 'ditty' condition in which a short song ("Think about the answer: don't tell me") was sung by an experimenter after stimulus presentation, children's performance would improve relative to a standard 'no ditty' condition. Diamond et al. found performance was indeed better when the 'ditty' was chanted between stimulus presentation and response, than when the ditty was not chanted. As a result, the authors suggest a delay of several seconds is enough to positively impact on performance. When children have additional time in which to compute the appropriate response, accuracy will be improved.

Passive Dissipation (Simpson et al., 2012; Simpson & Riggs, 2007) suggests delay between stimulus presentation and response allows time for inappropriate prepotent responses to fade before an appropriate response rises. Using a Go/Nogo (Box Search) task Simpson & Riggs (2007) told children to open some cued boxes on go trials and leave boxes with an alternative cue shut on no-go trials. Importantly, the cue was only placed on the box after a

2-secs delay. Interestingly, they found that performance was better – children made fewer go errors - on no-go trials. According to Simpson & Riggs the enforced delay before responding allowed for the faster, but incorrect, prepotent response to fade before the slower, but correct, appropriate response could be provided.

Simpson et al. (2012 - Experiment 2) confirms the positive effects of delay on performance; moreover, that incorrect responses must fade before an appropriate response can be computed. Simpson and colleagues compared Active Computation (Diamond et al., 2002) and Passive Dissipation (Simpson et al. 2012; Simpson & Riggs, 2007) to investigate how response prepotency is created and overcome. Three conditions: immediate, delay and delay with distraction were used in a Box search task. The delay with distractor condition was used to stop children from actively thinking about the rules of the task during delay. Simpson et al. hypothesised that an inability to compute during the delay period would mean children would perform poorly on this task, but if children performed well on the delay with distraction condition then delay simply allowed inappropriate prepotent response to dissipate. Simpson et al. (2012 – Experiment 2) found that children did indeed perform well on the delay with distraction task: they resisted opening boxes on no-go trials despite being unable to compute the appropriate response during delay. The results are therefore consistent with Passive Dissipation (Simpson & Riggs, 2007): delay supports appropriate responding in SRC tasks as it gives incorrect prepotent responses time to fade before the appropriate response can rise.

Finally, Barker & Munakata (2015) have proposed the *Goal Reminder* account. They suggest that the manipulations used to achieve delay coincidentally improves performance on SRC tasks, and that delay conditions used in previous research actually encourage children to

remember the task rules; it is this, not delay, which improves performance. Investigating delay in SRC tasks Barker and Munakata (2015) manipulated delays and task-reminders in a Go/nogo box search task. They had 150 3-year-old's take part in five conditions: immediate no reminders, immediate with reminders, delay no reminders, delay with reminders and delay with reminders with a screen. The results supported a Goal Reminder account: there was little difference between the immediate and delay conditions - and task reminders, but not experimenter-imposed delays, reduced inappropriate box opening. The imposition of a delay does not in itself improve children's response inhibition; it was the task reminder that occurred during delay that improved SRC task performance.

Relatedly, Barker & Munakata (2015) question whether the findings of Diamond, Kirkham & Amso. (2002) and Simpson et al. (2012) are confounded. They suggest the ditty (Diamond, Kirkham & Amso., 2002) or additional instructions / distractor task (Simpson et al., 2012) provided during delay constitute a task reminder. As a result, task-relevant information may have been cued during delay and may have been the basis for improvements in performance. However, investigating the effect of task reminders on SRC task performance Ling, Wong & Diamond (2016) examined whether a ditty supports improved performance because it imposes a waiting time or because it includes task relevant information. Using standard (task relevant: "Think about the answer: don't tell me") and modified (non-task relevant: "I hope you have a nice time: I like you") 'ditty' conditions, they found children performed better (they had greater accuracy) on conditions that included the singing of a ditty. Interestingly, it didn't matter which of the two ditty conditions children were subject to: the singing of the ditty improved performance regardless of whether it did contain task relevant information or did not. Consequently, Ling et al. (2016) speak against the Goal Reminder account as they

suggest it is merely the imposition of a waiting time between stimulus presentation and response that serves to improve performance on SRC tasks. In essence, a delay allows inappropriate prepotent responses to subside before the correct response is provided.

When considering why delay works, then, it must be because delay reduces inhibitory demands in SRC tasks. However, despite a growing body of evidence that shows delay has performance effects, it is not clear whether it is *the* motivating factor for children's improved performance or if imposition of delay has other intrinsic effects. Thus, questions surrounding delay and its contribution to children's improved performance on Response-Given SRC tasks remain unanswered.

Task Conceptualisation

According to Simpson and Carroll (2018) children's conceptualisation of a task is key to whether it contains a goal-inappropriate response, and inhibitory demands. If/then rules (*if-A-then-B/if-B-then-A*) are central to SRC tasks: this rule structure means that the wrong response is primed on each trial. As a corollary of using an if/then rule, however, SRC tasks require inhibition to overcome inhibitory demands - and children's weak IC means they are difficult to overcome. It follows that where SRC task rules can be conceptualised as not containing a goal-inappropriate response, inhibitory demands will be reduced and children will not need to employ their weak IC to be successful. Simpson and Carroll (2018) identify two types of conceptualisation: *IC-requiring* and *IC-avoiding*. Conceptualisation of a task's rules in an if/then fashion means that the task will contain a goal-inappropriate response, and inhibitory demands, and is an *IC-requiring* conceptualisation. Conceptualisation of a task's

rules in any way other than if/then means the task will not contain a goal-inappropriate response, will have reduced inhibitory demands, and is an *IC-avoiding* conceptualisation.

In the first research of its kind, Simpson and Carroll (2018) used three experiments to investigate whether children can overcome a task's inhibitory demands if they can conceptualise it in the right way. The authors identified two different ways of presenting task instructions, one of which emphasised the *if-A-then-B, if-B-then-A* rule (e.g. 'when I say 'sun' point to the 'moon' card, and when I say 'moon' point to the 'sun' card'), and the other which emphasised an alternative – *IC-avoiding* – way (e.g. 'point to the other card'). Experiment 1 compared performance on two Verbal-cue tasks (1-rule and 2-rule versions of the Grass/Snow task e.g. Simpson & Riggs, 2009), and two marker-cued Box tasks (1-rule and 2-rule). The 1-rule Verbal-cue task used rules: 'when I name one card, you point at the other card. So, when I say 'sun' you point to the other card. And when I say 'moon' you point to the other card'. The 2-rule Verbal-cue task followed an '*if-stimulus-A-then-response-B/if-stimulus-B-then-response-A'* rule structure: 'when I say 'sun' you point to the moon card. And when I say 'moon' you point to the sun card'. The 1-rule Box task used rules: 'when I put the sticker in one box, point at the other box. So, when I put the sticker in the small box point at the other box, and when I put the sticker in the big box point at the other box'. The 2-rule Box task used rules: 'when I put the sticker in the small box point at the big box, and when I put the sticker in the big box point to the small box'. Importantly, the 1-rule versions of each task encouraged an *IC-avoiding* conceptualisation, the 2-rule versions encouraged an *IC-requiring* conceptualisation. Simpson and Carroll predicted performance would be better on the 1-rule task than the 2-rule task because the 1-rule task would not generate inhibitory demands,

whereas the 2-rule task would. The results were not consistent with their hypothesis, however: performance was poor on both the 1-rule and 2-rule Verbal-cue tasks.

In Experiment 2, Simpson and Carroll (2018) continued to investigate task conceptualisation in SRC tasks. They suggested pre-schoolers may yet be conceptualising the box task in an *IC-avoiding* way. That is, rather than using an *if-A-then-B, if-B-then-A* rule structure, children simply looked for the 'unmarked' location (e.g. point to the empty box); a rule that cannot be used in the Verbal-cue task. To compare marked and unmarked performance Simpson and Carroll devised two novel SRC tasks: a 2-Card task and a 4-Card task. The 2-card task used two picture cards, and the child and experimenter shared these cards to provide the prompt and response. A star-shaped marker identified the prompt card. The 2-Card task used rules 'when I put the star on the sun, point at the moon, when I put the star on the moon, point at the sun'. The 4-Card task used four picture cards. The child and experimenter had their own pair of cards. The experimenter cued the card using his own pair of cards, the child responded using her own pair of cards. Importantly, in the 2-Card task children could adopt an *IC-avoiding* conceptualisation (e.g. select the unmarked location) because a correct response would always mean children would point to the unmarked location; however, in the 4-card task the same rule could not be invoked: the cards the child would respond to were not marked. The 1-rule Box task and 2-rule Verbal-cue task (from Experiment 1) were included as baseline measures of performance. Simpson and Carroll made two predictions: (1) tasks that could be conceptualised in an *IC-avoiding* way (i.e. 2-Card task and 1-Rule Box task) would show good performance, (2) tasks that could not be conceptualised in an *IC-avoiding* way (i.e. 4-Card task and 2-Rule Verbal-cue task) would show poor performance. Additionally, they tested whether tasks are harder when responding is cued verbally (e.g. Verbal-cue task) or

physically (e.g. Box task). The results were consistent with the predictions: the 2-Card task was easier than the 4-Card task, and supported the hypothesis that conceptualisation of an SRC task as *IC-avoiding* leads to better performance.

In Experiment 3, Simpson and Carroll (2018) continued to investigate whether conceptualisation affects children's performance on an SRC task. They tested whether only differences in conceptualisation alter task performance It used three SRC tasks: a Standard card task (the same 4-Card task used in Experiment 2), a 1-Rule card task and a 2-Rule card task. Each task used 'sun' and 'moon' images. The 1-Rule card task used a single rule 'point the same way as me' – and so was an IC-avoiding task. The 2-Rule card task used standard SRC rules '*if-stimulus-A-then-response-B/if-stimulus B-then-response A'* – and so was an *IC-requiring* task. Additionally, in Experiment 3 the arrangement of cards in the 1-Rule and 2-Rule tasks were different to the Standard task; the cards were arranged adjacent to one another (see Fig 1.2). This meant that when children provided a correct response they would be mirroring the experimenter's action (e.g. when experimenter points to 'sun' card, child points to 'moon' card'). In other words, children could choose to adopt an *IC-requiring or IC-avoiding* conceptualisation or not. Given the different rule structures and arrangements of picture cards, Simpson & Carroll predicted that performance on tasks which could be conceptualised as *IC-avoiding* (e.g. 1-Rule card task) would be better than on tasks conceptualised as *IC-requiring* (e.g. 2-Rule card task and Standard card task). Results supported the predictions: 1 Rule performance was best, followed by 2-Rule performance and then Standard card task performance.

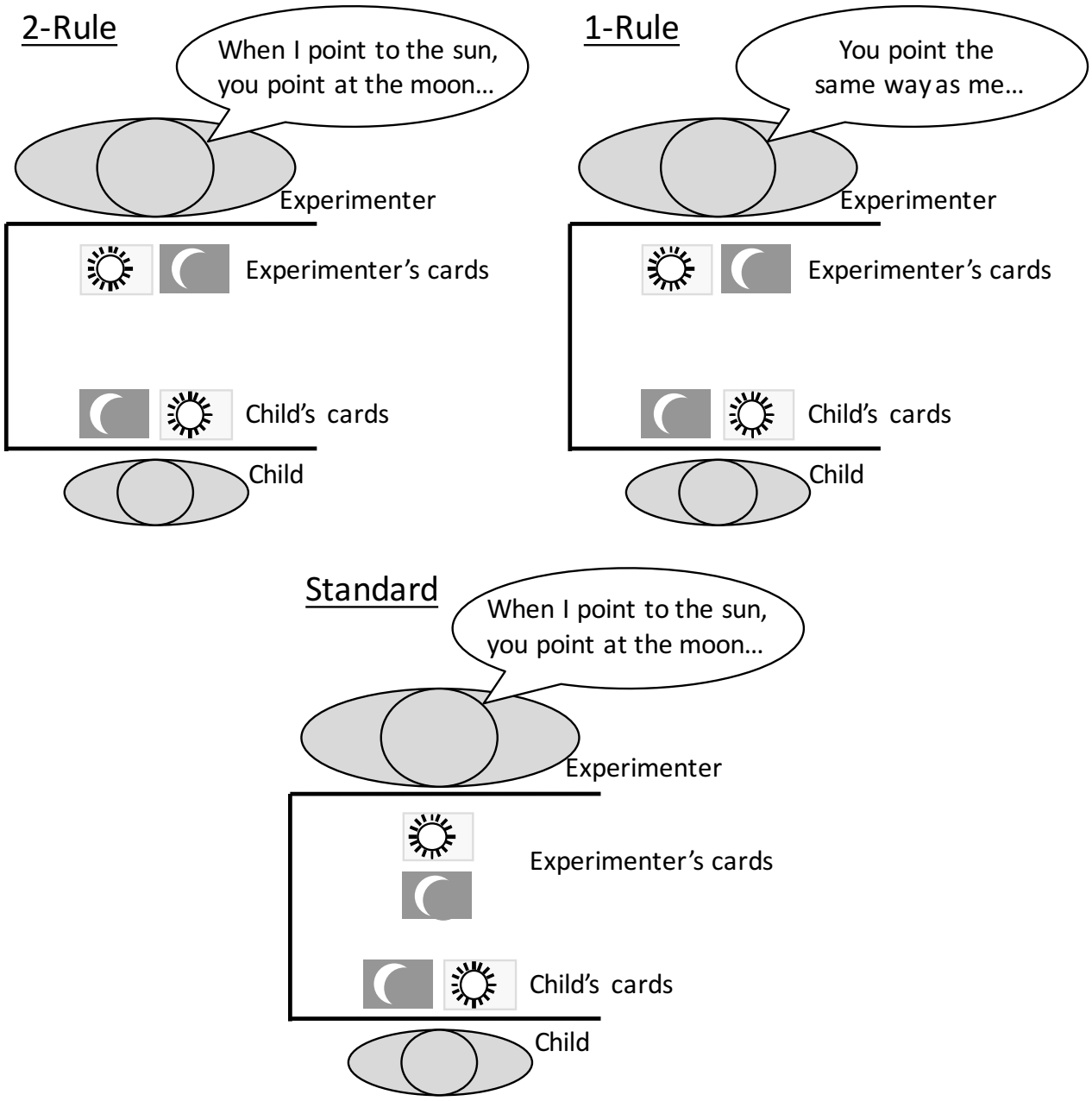


Figure 1.2. Schematic representation of the card arrangements and instructions given in the 4-Card tasks used in Experiment 3 (taken from Simpson & Carroll, 2018).

Taken together, the results of Experiments 2 and 3 (Simpson & Carroll, 2018) suggest task conceptualisation is key to the establishment of inhibitory demands in SRC tasks. Conceptualisation of a task as '*IC-requiring*' leads to poor performance, presumably because children's weak IC cannot suppress the prepotent response. In contrast, conceptualisation of

SRC tasks as '*IC-avoiding*' leads to good performance, presumably because prepotent responses and inhibitory demands are not activated, and inhibitory control is therefore not needed to suppress them. In other words, conceptualising a task in an *IC-avoiding* way reduces the inhibitory demands of the task. It follows that where children can conceptualise SRC tasks as not containing inhibitory demands (an *IC-avoiding* strategy) performance will be better than on tasks that do contain inhibitory demands (an *IC-requiring* strategy).

Not all SRC tasks may be conceptualised in an *IC-avoiding* way, however e.g. Hand Game (Calderon, Jambaque, Bonnet & Angeard, 2014; Earhart & Roberts, 2014; Simpson & Carroll, 2011; Simpson & Carroll, 2014), Grass/Snow task (Simpson & Riggs, 2009), and Day-Night task (Gerstadt et al., 1994; Simpson & Riggs, 2005a). The Day-Night task (Gerstadt et al., 1994), for example, is similar to the Box and 2-Card tasks used by Simpson and Carroll (2018) in that it also consists of an *if-A--then-B/if-B-then-A* rule. However, unlike the Box task or 2-Card task, the Day-Night task cannot be conceptualised in an *IC-avoiding* way because there is no empty location that can be used as a marker, nor can children 'point the same way as the experimenter'. Children need to determine which stimulus has been cued and then apply the *if-A-then-B/if-B-then-A* rule. As a result, the inhibitory demands of the task are high, and children must employ their (weak) IC to be successful.

How young children conceptualise a task is influential in the creation of inhibitory demands. Simpson & Carroll (2018) suggest conceptualisation has tangible benefits for young children's SRC task performance. Conceptualisation essentially works on the principle of Occam's Razor - the simplest interpretation is usually the best one: although children almost certainly won't think in terms of 'let's reduce the inhibitory demands of this task', a reduction in inhibitory

demands will be an added 'bonus' as a function of simplifying the task rules. This suggests that wherever possible children may attempt to conceptualise tasks in *IC-avoiding* ways. However, not all Response-Given tasks consist of an *if-A-then-B/if-B-then-A* rule structure that requires children to choose between two responses e.g. Go/no-go and Simple. Thus, it is only when the task structure allows children to simplify the task rules that inhibitory demands may be reduced. In tasks that have no defined responses - Open tasks, for example - children must engage in a reasoning process which culminates in a single self-defined choice of response. In Open tasks it is clear that how children conceptualise the task has important and profound effects on the tasks' inhibitory demands.

1.5 Open tasks

In this section I discuss Open tasks. Specifically, I consider the processes that create, and manipulations that reduce, inhibitory demands in Open tasks. Open tasks differ from Response-Given tasks in an important respect: Open tasks do not have a defined set of responses. In Open tasks children must reason about information they have been provided with, and offer their response based on an evaluation of the information. That is, in order to pass an Open task, children must engage in a thoughtful and deliberate thinking process before providing a response.

1.5.1 What conditions create the inhibitory demands of Open tasks?

The inhibitory demands of Open tasks and Response-Given tasks are created in a different manner. This must be so, because the tasks themselves are so dissimilar. In Response-Given tasks children must select one response from a set of two provided by the experimenter. Children's intention to give a response means it becomes prepotent (e.g. see 'Sun', say 'Day').

Open tasks, however, require children to reason about their response to information presented in a task. Thus, in Open tasks children may infer any response. No response is made prepotent by being planned before the task begins. Given the dissimilarity between Open tasks and Response-Given tasks, their inhibitory demands must therefore be created differently. I propose three conditions underlie the creation of inhibitory demands in Open tasks (1) an incorrect a response is initially generated, (2) the appropriateness of this response is doubted, and (3) a correct response can be generated. Under these conditions IC is required to inhibit the incorrect response and instead apply the correct response.

Consider the following type of Open task, the Counterfactual Reasoning Task (e.g. Beck et al., 2011), which requires children to engage in a reasoning process and consider the world as it would be given that an event has not occurred (see Beck, Weisberg, Burns & Riggs, 2013, for a review). For example, an object is initially placed in location A, but event X causes it to be moved to location B. Children are then asked where the object would be located had event X not occurred. Children who answer correctly choose location A. In this example, the three conditions I propose to underlie the creation of inhibitory demands in Open tasks can apply in the following way. (1) A child's initial – but wrong – response is generated (location B), simply because the obvious answer to a question about an objects location is its location; (2) they doubt the appropriateness of this response; and (3) consider an alternative – and correct – response (location A). Inhibitory control is required to inhibit the initial and wrong response (location B) to give time for the correct response to be generated (location A).

1.5.2 How may inhibitory demands of Open tasks be limited?

In this section I discuss how inhibitory demands of Open tasks may be limited. I propose that this may occur in three ways: (1) Delay, (2) Response Mode Effects, and (3) Task Conceptualisation. Delay limits inhibitory demands due to the greater time elicited between stimulus presentation and response; the Response Mode Effect works as a function of the different ways in which responding occurs; and Task Conceptualisation suggests adopting an *IC-avoiding* conceptualisation will reduce inhibitory demands.

Firstly, delaying responding in Open tasks shows concomitant improvements in performance (Carroll, Blakey and Simpson., submitted; Beck et al., 2011). In this way, the effect of delay in Open tasks is similar to its effect in Response-Given tasks (e.g. Diamond et al., 2002; Ling, Hong & Diamond., 2016; Montgomery & Fosco, 2012): performance improves. In their investigation of how delay may bring about Delay effects Carroll et al. (submitted) used three Open tasks and one Response-Given task. Results showed a response speed effect in two Open tasks (Strategic Reasoning and Counterfactual Reasoning) and the Response-Given task (the Grass/Snow task). In these tasks, it is assumed delay helps children to overcome inhibitory demands, although definitive understanding of what they are doing during the delay period is yet to be fully resolved (Barker & Munakata, 2015; Diamond et al., 2002; Simpson et al., 2012; Simpson & Riggs, 2007). However, given that improvements in performance are observed in Open tasks that utilise delay, we can be confident Open task inhibitory demands are also limited as a function of slowing responding.

In section 1.4.3 I suggested improvements in performance as a function of delay in Response-Given tasks may occur in three ways: Passive Dissipation (Simpson et al., 2012; Simpson &

Riggs, 2007), Goal Reminders (Barker & Munakata, 2015) and Active Computation (Diamond et al., 2002). In Response-Given tasks Passive Dissipation improves performance by allowing time for an inappropriate response to rise and fade before the production and selection of an appropriate response. In contrast, in Open tasks Passive Dissipation cannot explain better performance as a function of delay. By definition, Open tasks must contain prepotent responses because they are inhibitory tasks. However, Open tasks do not contain only a set of two responses from which a single response must be selected. Therefore, in Open tasks responses are not prepotent because they are *automatically triggered* by a stimulus, but presumably because they provide the obvious or default answer to the question set in an Open task. Thus, as no automatically-triggered prepotent response rises and needs to fade before an appropriate response is generated, Passive Dissipation is unable to explain improvements in Open task performance.

The Goal Reminder (Barker & Munakata, 2015) account is similarly unable to explain improved performance on Open tasks as a function of delay. On this account children's performance improvements are achieved via task rule-oriented cues during delay that promote focus on, and contemplation of, the task's rules. It is this process that leads to better performance. Given that Open tasks, for example, the Counterfactual Reasoning task (e.g. Beck et al., 2011), contains no rules – only a story about a sequence of events and the consequences of those events – the Goal Reminder (Barker & Munakata, 2015) account cannot reasonably explain improvements in children's performance as a function of delay. There are no rules to be reminded of in Open tasks.

The third account of how performance improves as a function of delay – Active Computation (Diamond et al., 2002) – suggests provision of delay allows children time to think about correct responses. As a consequence, it is this account which best explains how delay improves performance on Open tasks (Carroll et al., submitted). In Open tasks children must engage in a thoughtful process to effect successful problem resolution. A number of prepotent response options may be initially generated, albeit that a different process from that employed in Response-Given tasks makes them prepotent: in Open tasks the initial and prepotent responses are a function of basic reasoning procedures and reflect the child's 'best first guess'. However, a 'best first guess' may be wrong. Where this is so, the imposition of delay plays an important part in allowing children to generate alternative responses to their 'best first guess', reflect on their appropriateness and choose which response to provide.

Second, the Response Mode Effect refers to the improvement of task accuracy as a function of different modes of responding (e.g. Carroll, Fitzgibbon & Critchley, 2014). Response Mode effects are shown in Open tasks, such as: Counterfactual Reasoning / Syllogistic Reasoning (Beck et al., 2011); and Strategic Reasoning (Carroll et al., submitted; Carroll et al., 2014; Carlson, Moses and Hicks, 1998; Carroll, Riggs, Apperly, Graham & Geoghegan, 2012; Hala & Russell, 2001; Russell et al., 2003), but not a False-Belief task (Carroll et al., 2012; Caroll et al., submitted). In one of the earliest studies of Response Mode Effect in Open tasks, Carlson, Moses and Hix (1998) showed that when replacing veridical pointing with the placement of a pictorial cue on a box or by using a rotating arrow, children were more likely to deceive their opponent. Other non-standard (novel) modes of responding include: hoops (Simpson & Riggs, 2007), hand-held arrows (Carroll et al., submitted; Carroll et al., 2014; Carroll et al., 2012; Beck et al., 2011), mounted cardboard hands (Hala and Russell 2001), button pressing

(Simpson and Riggs, 2006; Flynn O'Malley and Wood, 2004; Russell, Hala & Hill, 2003; Perner & Lang, 2002; Luria, 1959), and stickers (Hala & Russell, 2000).

In more recent research on Response Mode Effects in Open tasks, Carroll and colleagues (submitted) investigated how response-based changes affected young children's reasoning and executive function. Using three Open tasks (Strategic Reasoning, Counterfactual Reasoning, False Belief) and one Response-Given task (Grass/Snow) they varied the mode of responding: participants either pointed their finger or used a hand-held arrow. They showed a Response Mode Effect in the Strategic Reasoning task, but not the Counterfactual Reasoning, False Belief or Grass/Snow tasks. The findings are broadly consistent with other research (e.g. Carroll et al., 2012; Simpson & Riggs, 2009), although not all (Beck et al., 2011), and provide more evidence that using alternative response modes improves performance on some tasks but not others. However, it is suggested that the Response Mode Effect is much more limited than the delay effect.

Whilst Response Mode Effects may account for improved task performance, it is also conceivable alternative features of non-standard responses promote greater accuracy (see Carroll et al., submitted). Consider the act of placing a hoop on a box (Simpson & Riggs, 2007). Manual actions such as this are arguably rapid, but not more so than pointing a finger. Placing a hoop on a box requires the extension of the arm and positioning of the hand and hoop over a box, before the placement of the hoop on top of the box. When compared to pointing a finger, placing a hoop on a box is comparatively slow. It is this extended period of time before completion of responding that allows for the appropriate answer to be worked out. In other words, the defining feature of novel response methods that promotes better performance is

not the novel response, but the delay in responding as a function of the novel response method. Taken together, developmental research shows there are positive effects of using novel modes of responding on IC task performance, although it is not clear which aspect of the novel response leads to better performance. Thus, at present it is not obvious whether non-standard forms of responding improve children's task performance or whether delay as a function of novel modes of responding contributes to a greater extent instead.

Third, in section 1.4.3, I suggested the way in which Response-Given tasks were conceptualised had an effect on whether the task contained a goal-inappropriate response and inhibitory demands, and which ultimately affected children's performance. Conceptualising a task in an *IC-requiring* way leads to the establishment of inhibitory demands – and decreased accuracy; conceptualising a task in an *IC-avoiding* way leads to a reduction in inhibitory demands – and improved accuracy. Conceptualising in an *IC-avoiding* way may only be possible on Response-Given tasks that allow children to escape thinking of the rules in an *if-A-then-B/if-B-then-A* manner, however. Simpson & Carroll's (2018 – Experiment 1) Box task is a good example: children may simply conceptualise the rules as 'point to the unmarked box'. However, children cannot conceptualise rules of the Hand Game (Calderon, Jambaque, Bonnet & Angeard, 2014; Earhart & Roberts, 2014; Simpson & Carroll, 2014), Day-Night task (Simpson & Riggs, 2005a; Gerstadt et al., 1994) and Grass/Snow task (Simpson & Riggs, 2009) in an *IC-avoiding* way. In these tasks there is no external, physical marker that cues stimulus choice: children need to determine which stimulus has been cued and then apply the *if-A-then-B/if-B-then-A* rule.

Children have much more flexibility when conceptualising an Open task. It is therefore possible that two Open tasks, which seem superficially similar may be distinguished by the way they are conceptualised. One Open task may have high inhibitory demands because children tend to conceptualise it in an IC-requiring way, while another has low inhibitory demands because children conceptualise it in an IC-avoiding way.

Consider two such tasks: Counterfactual Reasoning and Future Hypothetical Reasoning. In Counterfactual Reasoning tasks children are asked how a current location of an object would be different if the past were to be different. For example, in Beck et al. (2011) children are asked if a gust of wind had not blown, would a picture still be on a table or in a tree? In Future Hypothetical Reasoning tasks children are asked how a future location of an object would be different from its current location. For example, Beck, Robinson, Carroll and Apperly (2006) had children take part in a game in which a mouse could run down one of two slides, and were then asked 'what if next time he goes the other way?'. Interestingly, although Counterfactual Reasoning and Future Hypothetical tasks are ostensibly similar, young children's performance on them is strikingly different: Counterfactual Reasoning tasks are difficult, Future Hypothetical tasks are easy. Simpson and Carroll (2018) suggest conceptualisation may explain this difference in task difficulty: in Future Hypothetical tasks an *IC-avoiding* conceptualisation is adopted because children understand that the current location of the object is not relevant to its future location – and so do not need to employ their (weak) inhibitory control. In Counterfactual Reasoning tasks an *IC-requiring* strategy is adopted because children do not understand that the current location is not relevant - and therefore they do need to employ their (weak) inhibitory control. In short, whether or not an

Open task is difficult or easy simply depends upon its conceptualisation in an *IC-requiring* or *IC-avoiding* way.

1.6. This Thesis

This thesis focuses on the creation and avoidance of inhibitory demands in inhibitory tasks. The first difference I have identified is in resisting prepotent responding in Manual and Verbal imitation tasks: Manual tasks are difficult, Verbal tasks are easy. A second difference I have identified is between Reverse Sort and Grass/Snow tasks: the Reverse Sort task is easier than the Grass/Snow task. My initial intention was to investigate these two pairs of Response-Given task, and then to move on to an Open task. However, it proved harder than expected to determine why verbal imitation is sometimes easier to resist than manual imitation. A total of six experiments were required to address this question (Chapters 2 and 3). This meant that while I was able to address the difference between the Reverse Sort and Grass/Snow task (Chapter 4), I was unable to investigate Open tasks.

SRC tasks are difficult when inhibitory demands are high (Gerstadt et al., 1994; Simpson et al., 2006; Simpson & Riggs, 2005b; Simpson & Riggs, 2009). Manual imitation research shows children find it difficult to resist copying the manual behaviour of others in SRC tasks (e.g. Diamond & Taylor, 1996), and is therefore commensurate with the idea that Manual tasks have high inhibitory demands. In contrast, not copying the speech of others is easy in Verbal imitation tasks (Simpson, Cooper, Gillmeister & Riggs., 2013), and is consistent with these tasks possessing low inhibitory demands. Simpson & Carroll (2014) suggest low inhibitory demands in Verbal imitation tasks is due to verbal imitation being a 'special case'. That is, the complexity of words (Simpson et al., 2013) means inhibitory demands are low. The

experiments presented in Chapter 2 and Chapter 3 build on empirical studies carried out by Simpson et al. (2013) and Simpson et al. (2014).

Chapter 2, Experiments 1, 2a and 2b investigate differences in inhibitory demands in Manual and Verbal imitation tasks. These experiments use one Manual task - the Hand Game (e.g. Hughes, 1996), and up to three Verbal tasks – Words (e.g. 'dog and 'cup'); Vowels (e.g. 'Ooo' and 'Eee'); and Syllables (e.g. 'Woo' and 'Boo'). In Chapter 2 I investigate the Word Complexity Hypothesis (Simpson et al., 2013; Simpson et al., 2014). It suggests verbal imitation is as prepotent as manual imitation, however, the correct stimuli must be tested: simple syllables not complex words. Words are not prepotent because their complexity interferes with the mapping between perceptual and motor representations. I want to understand whether the complexity of words supports children in successfully suppressing verbal imitation.

Chapter 3 consists of three experiments, which build upon the findings contained in Chapter 2, and focus on Verbal imitation. Initial interpretation of data in Chapter 2 shows Manual & Syllable conditions are both harder than the Word condition, and support the Word Complexity Hypothesis (Simpson et al., 2013; Simpson & Carroll, 2014). However, during data analysis I noticed a difference between the Syllable and Word conditions: the Syllables ('Woo' and 'Boo') rhymed but the Words ('Dog' and 'Cup') didn't. This difference may have accounted for better performance on the Word condition. Experiments 3, 4 and 5 therefore tested an alternative hypothesis: the Word Dissimilarity Hypothesis. It suggests that verbal imitation is easier to resist when the stimulus and response are different. For example, it is easy to resist verbal imitation when hearing "drum" and saying "plate", but hard when hearing "crab" and saying "grab". Under this hypothesis it is word *dissimilarity* that

contributes to children's ease with resisting verbal imitation. The results were consistent with this proposal. That is, when the words a child is planning to say are dissimilar from those heard (e.g. 'cat' and 'sun'), it is easy to resist verbal imitation.

In Chapter 4, Experiments 6, 7 and 8, I investigated why the Reverse Sort task is easier to resist than the Grass/Snow task. Reverse Sort tasks are visually cued, card-sorting response tasks. They typically require children to sort cue cards into an appropriate sorting tray; for example, children sort a 'sun' card into the 'moon' tray, and a 'moon' card into the 'sun' tray. In contrast, the Grass/Snow task (Simpson & Riggs, 2009; Carlson & Moses, 2001) is a verbally cued, pointing response task. It requires children to point to a white square when the experimenter says 'grass', and to a green square when the experimenter says 'snow'. When compared, however, performance on Reverse Sort tasks is better at an earlier age than performance on the Grass/Snow task (see Peterson, 2016, Figure 2). In Experiments 6, 7 and 8 I wanted to find out what underlies this better performance on the Reverse Sort task. I first considered Conceptualisation. Under this account, the Reverse Sort task is easier than the Grass Snow task because its rules can be conceptualised in an *IC-avoiding* way. However, the results were not consistent with this account. I then considered Delay. Under this account, the Reverse Sort task is easier because children respond more slowly when sorting cards, and slower responding reduces inhibitory demands.

Chapter 2

Does the complexity of words explain why children are more accurate at resisting verbal imitation than manual Imitation?

2.1 Introduction

In the last 30 years a growing body of developmental studies have used Complex tasks in which resisting manual imitation is assumed to require IC. In these studies children are typically required to operate two rules whilst inhibiting a prepotent manual response. Complex tasks used to explore prepotency of manual imitation include: Hand Game (Hughes, 1996), Knock and Tap (Korkman, Kirk & Kemp, 1998) and Peg Tapping (Diamond & Taylor, 1996). More recently, studies of Verbal imitation (Simpson et al., 2013; Simpson & Riggs, 2014) have also utilised Complex tasks to investigate IC. In these studies children must hold a dominant verbal response in working memory *and* inhibit a prepotent verbal response. In Chapter 2 I discuss and compare young children's performance on Manual and Verbal imitation tasks.

2.1.1 Tasks in which children resist manual imitation

In this section I discuss Manual imitation tasks. I begin by identifying Manual imitation tasks as those tasks which utilise manual actions as both stimuli and responses, and which require children to resist imitation of manual actions made by an experimenter. I then consider what the results of Manual imitation tasks say about IC.

The Hand Game (e.g. Blankenship, Slough, Calkins, Deater-Deckard, Kim-Spoon & Bell, 2019; Hughes, 1996; Hughes, 1998a; Korkman & Peltomaa, 1991; Simpson & Riggs, 2011) is the most commonly used Manual imitation task (see Table 2.1, Appendix 1). In the Hand Game children must always resist prepotent manual responding to a visually observed manual stimulus. Manual gesture response sets in early studies included fist making and finger

pointing (e.g. Hughes, 1996, Hughes, 1998a, Hughes, 1998b; Korkman & Peltomaa, 1991). This response set requires children to point their finger when an experimenter makes a fist, and make a fist when an experimenter points their finger. Response variants in later Hand Game studies included fists and flat hand on table (Blankenship et al., 2019; Lang & Perner, 2002), pointing with one or two fingers (e.g. Olson, Tardif & Miller, 2011), and thumbs-up, fingers-as-scissors, hands-up and hands-down (Simpson et al., 2013 – Experiment 3). The Hand Game is based on Luria, Pribram and Homskaya's (1964) original study with neuropsychological patients. It is normally used with preschool children aged 29 to 63 months (see Peterson et al., 2016), although exceptions to this age range exist (e.g. Korkman & Peltomaa, 1991, who used the Hand Game to investigate attentional problems in children aged 7-years-old).

Initial research conducted using the Hand Game with pre-schoolers (e.g. Hughes, 1996) showed it was very difficult for children aged 2.6-years-old to 3.5-years-old, with only three out of 14 able to give a correct response (point their finger when the experimenter made a fist). Of those who were unsuccessful most simply imitated the manual gesture of the experimenter: they pointed a finger when the experimenter pointed a finger, and made a fist when the experimenter made a fist. In contrast, all children aged 4-years-old reportedly performed well on the task. More recent research is consistent with the finding that older children perform better than younger children on the Hand Game (e.g. Peterson et al., 2016; Simpson and Riggs, 2011). Interestingly, in their meta-analysis of age-ranges of usefulness of inhibitory tasks Peterson et al. (2016) discuss that the Hand Game outlives its usefulness as a test of IC earlier than other similar SRC tasks (e.g. Day-Night task - Gerstadt et al., 1994; and Grass/Snow task - Simpson and Riggs, 2009). Peterson et al. suggest this may be due to the arbitrary associations inherent in the Hand Game, contrasted to the pre-established

associations inherent in the Day-Night and Grass/Snow tasks: the ability to resist imitating responses in short-term learned association tasks in the Hand Game (e.g. when experimenter points their finger, child points their finger) is easier than resisting long-held stimuli-response associations in the Day-Night task (e.g. say Day to 'sun' image, say Night to 'moon' image).

The Knock and Tap task (Korkman, 1988) is a test of inhibition and control, and is a commonly used Manual imitation task (see Table 2.1, Appendix 1). In Korkman (1988), the Knock and Tap task required children simply to tap a table when the experimenter knocks, and knock when the experimenter taps. However, it is not clear what the to-be-inhibited manual gesture is in this study as the information is not included in the methodology. One of the first studies to include details of the to-be-inhibited manual gesture is Klenberg, Korkman & Lahti-Nuutila (2001). In this study children had to tap once with the side of their fist when the experimenter knocked with their knuckles, and knock with their knuckles when the experimenter tapped with the side of their fist. Later stimuli and response variations on the Knock and Tap task had children tap a table with an open-handed palm when the experimenter knocked a table with their fist, and knock a table with their fist when the experimenter tapped with their palm (Joseph, McGrath and Tager-Flusberg, 2005; Lonigan, Lerner, Goodrich, Farrington & Allan, 2016), and use finger and fist gestures to knock or tap on tables (Nampiijja et al., 2010). The Knock and Tap task is an anti-imitation task, and is based on Luria, Pribram & Homskaya (1964): young children must produce an opposite manual response to that fashioned by an experimenter. In this sense it is similar to the Hand Game: an automatic manual gesture must be resisted. However, the Knock and Tap task is dissimilar to the Hand Game in that the former task requires children to resist an automatic manual gesture and then interact with an external object (i.e. a table), whereas in the latter task children must simply resist production of an automatic manual gesture (e.g. fist or pointed finger).

First used to assess neuropsychological development, the Knock and Tap task is one of a battery of tasks that together form 'A Developmental Neuropsychological Assessment' tool – NEPSY (Korkman, 1988). As part of NEPSY, the Knock and Tap task is used to investigate inhibition and control in children with learning disabilities. Results of studies that used the Knock and Tap task for these purposes showed, for example, that very low birth weight children aged 5-years-old to 9-years-old performed worse on it than did a control group of similar aged children (Korkman, Liikanen and Fellman, 1996). More recently, the Knock and Tap task has been used with typically developing preschool children. Peterson and colleagues (2016) meta-analysis of Knock and Tap task studies depicts an irregular pattern of performance: accuracy is good at 36-months and increases until approximately 45-months. However, between 45 months and 60 months accuracy decreases, before increasing to a higher level of accuracy than the 36-month to 45-month period, and then levelling off. Peterson and colleagues explain this pattern of performance in terms of decreases in systematic missingness with age. In other words, with increasing age, more less-skilled children complete the task, and it is this that lowers average group scores.

The Peg Tapping task (Diamond & Taylor, 1996) is a commonly used manual imitation task (see Table 2.1, Appendix 1) and was initially used with children aged 3-years-old to 7-years-old. The Peg Tapping task requires children to resist production of automatic manual responses to manual stimuli (although see Becker, Isaac & Hynd, 1987; Passler, Isaac & Hynd, 1985, for a variation of the Peg Tapping task that requires resisting a manual tapping response to a non-visual tapping stimuli). The Peg Tapping task typically requires children to use a wooden dowel (Bowmer, Mason, Knight & Welch, 2018; Brown, Moore & Ackerman, 2013; Diamond & Taylor, 1996; Fay-Stammbach & Hawes, 2018; Oh & Lewis, 2008) to tap a table an

opposite amount of times as demonstrated by the experimenter: they tap once when the experimenter taps twice, and twice when the experimenter taps once. However, more recently, stimuli and response variants include tapping with pegs (Zelazo, Forston, Masten & Carlson, 2018), pens (Slot & von Suchodoletz, 2018), pencils (Goble, Sandilos & Pianta, 2019; Roberts & Powell, 2005; Spiegel & Lonigan, 2018; Walczak & Chrzan-Dętkoś, 2018), and hammers (Ma, Chen, Xu, Lee & Heyman, 2018). The Peg Tapping task is developed from the Luria et al. (1964) original study with neuropsychological patients. More recently it has been utilised as one of a battery of IC tasks that together form the 'Pre-school Self-Regulation Assessment' (Smith-Donald, Raver, Hayes & Richardson, 2007).

Diamond & Taylor (1996) first used the Peg Tapping task to investigate young children's ability to hold two rules in mind whilst inhibiting a prepotent manual response. They hypothesised performance would improve as a function of age: older children would be more accurate than younger children. Their results showed children aged 7-years-old did indeed perform better than children aged 3.5-years-old on a range of Manual imitation task measures, including: task accuracy, performance maintenance across test trials and decreased pre-test failure rates. The results are also consistent with research that shows rapid improvement in IC between 3-years-old to 4-years-old (Gerstadt et al., 1994; Simpson et al., 2005a).

The Peg Tapping task is similar to the Hand Game and Knock and Tap tasks: an automatic manual response must be resisted. However, the Peg Tapping task is dissimilar to the Hand Game and Knock and Tap tasks in that it requires children to use an object to produce the opposite manual response (i.e. the tapping gesture), whereas in the Hand Game and Knock and Tap tasks the hand gesture *is* the manual response. Furthermore, in the Peg Tapping task

children must also resist imitating the tapping frequency exhibited by the experimenter, unlike the Hand Game and Knock and Tap tasks in which children must point their finger or show their fist, or knock or tap the same frequency of times as the experimenter e.g. the experimenter knocks once so the child taps once. Overall, research utilising manual imitation tasks such as the Hand Game (Hughes, 1996), Knock and Tap (e.g. Lonigan et al., 2016) and Peg Tapping (e.g. Diamond & Taylor, 1996) tasks suggests that manual imitation seems hard to resist whatever the gesture and whether or not it involves interaction with an object.

2.1.2 What theories suggest manual imitation is automatic?

This section focuses on how theories of human action explain manual imitation automaticity. I begin by discussing two theories of imitation: Ideomotor Theory (e.g. James, 1890) and Associative Sequence Learning (Heyes, 2001). The Ideomotor approach suggests that actions are linked to the intended outcome of those actions; a sensorimotor approach suggests action are linked to observed actions. I then discuss how the mirror system and mirror neurons give empirical support to these two theories.

Initially proposed by James (1890), Ideomotor theories state that intended or actual perceptions are intrinsically linked to representations of action. More recently Greenwald (1970) has suggested an outcome associated with performing an action – its effect – activates motor representations of action. In their review of Ideomotor Theory, Shin and colleagues (Shin, Proctor & Capaldi, 2010) characterise it as a 'framework for action planning'. As a result of its long history and many theoretical revisions, Ideomotor theory provides a range of explanations for the same event, say, the unlocking of a door. Under an Intended perception account it is the *intention* to open a door that activates a motor representation of the action

plan. Consistent with an Actual perception account it is the *actual* perception of a door being unlocked that activates a motor representation. In line with an Outcome account, it is the effect of a motor action - the door being unlocked - that activates the motor representation. Regardless of the account or revision promulgated, taken together Ideomotor theory suggests there is a tight linkage between internal images of action and the action itself.

A tight linkage between perception and action is commensurate with the view that perception and action planning share a single representation. That is, sensory and motor codes share certain features - they have a *common code* (e.g. Prinz, 1992). In this way, representations of manual action are fundamental to their perception, and production. Motor representations are involved in coding perceived motor action, and motor action is stimulated by perception of action. In other words, and according to the common code, perception of action *will* result in the production of a motor action. As such, Ideomotor Theory suggests imitation is an inevitable and inescapable consequence of perceiving action. In other words, manual imitation is automatic.

Associative Sequence Learning theory (Heyes, 2001) is a sensorimotor account of imitation. It argues imitation occurs through associations between sensory perceptions and motor representations formed via sensorimotor learning. Importantly, these links are formed through temporal contiguity and contingency. Temporal contiguity suggests that sensory and motor representations which occur closer together in time become linked. Contingency relates to the predictive ability of an action to another action. More simply, according to Associative Sequence Learning theory sensorimotor links are formed as a function of their temporal closeness and predictive nature. The principles of temporal contiguity and

contingency neatly explain why some motor representations and motor actions do and do not become linked. Consider, for example, a person who accidentally pokes themselves in the eye just at the same instant as the person they are in conversation with sneezes. The poke in the eye and the sneeze have temporal contiguity – they occur at the same time; importantly, however, there is no sensitivity to contingency - sneezing is not predictive of poking oneself in the eye. Therefore, the poke in the eye and sneezing do not become linked.

Results from adult studies on automatic imitation show sensorimotor learning is integral to imitation. Sturmer, Aschersleben & Prinz (2000), for example, showed human hand opening is expedited by observation of a compatible human hand opening action. Elsewhere, this finding has been replicated in studies that use non-human stimuli. Press, Gillmeister and Heyes (2007) investigated whether observation of robotic hands performing a hand action contributed to automatic imitation, and found that in a compatible condition hand opening was faster than in an incompatible condition. Taken together, these and many other studies suggest sensorimotor learning promotes automatic imitation.

Researchers investigating the neural bases of imitation (see Chambers, Garavan & Bellgrove, 2009, for a review) have been successful in advancing understanding of the cognitive architecture underlying automatic imitation. The Mirror Neuron System was first detected in lower primates (Gallese, Fadiga, Fogassi & Rizzolatti, 1996; Rizzolatti, Fadiga, Gallese & Fogassi, 1996). Mirror neuron's fire when an action is observed; they also fire when the observer carries out the observed action. More recently, Cross & Iacoboni (2014) have found further support for the imitative nature of mirror neurons. They found that before a manual

action is carried out mirror neurons either increase in activity in comparison to a baseline activity level if the action is imitative, or decrease in activity if the action is counter-imitative.

The discovery of the mirror system and mirror neurons provides empirical and physiological support for the common code idea espoused by Ideomotor Theory. Under Ideomotor Theory actions are encoded in terms of their effects, and effect-based action plans come about through action-effect learning (Bunlon, Marshall, Quandt and Bouquet, 2015). That is, the performance of an action leads to the identification and integration of perceptual codes required to perform the motor action – and a bi-directional code is formed. Mirror neurons, therefore, are well-placed to be considered as the neural substrate for this common code. Mirror neurons fire when an action is observed, and also when that action is being performed. In this sense they play a key neurological role in understanding the actions of selves and others. Importantly, mirror neurons are commensurate with Prinz' Ideomotor conception that representation of action is functionally important to production of action. Mirror neurons fire when an action effect is observed and in doing so provide the basis for the motor representation of that action. That being so, the mirror system and mirror neurons suggest manual imitation is automatic.

Associative Sequence Learning (Heyes, 2001) theory is also compatible with the presence of the mirror system and mirror neurons (Cook, Bird, Catmur, Press and Heyes, 2014). Properties of mirror neurons are acquired through learning. Associations between sensory perceptions and motor representations are the result of excitatory links developing between sensory and motor neurons. It is these neurons which then serve to act as primers for action: sensory Cell A fires and activates motor Cell B. For example, Cell A is activated on observing a hand opening

action and, through linkages developed temporally and predictively, fires Cell B, the motor representation of that action. Correlated and excitatory links between sensory and motor neurons strengthen and become a critical component in the imitative process: when the sensory neuron is activated the corresponding motor neuron fires. Consequently, knowledge of mirror neurons bolsters an Associative Sequence Learning account of imitation as automatic: action perception inexorably leads to the activation of a corresponding motor component (Heyes & Bird, 2007). As a result, manual imitation is automatic.

2.1.3. Tasks in which children resist verbal imitation

In this section I identify the Verbal imitation task (Simpson et al., 2013) as a task which utilises verbal actions as both stimuli and responses, and which requires children to resist imitation of verbal actions made by an experimenter. I then consider what the results of Verbal imitation tasks say about IC.

The Verbal Imitation task (Simpson et al., 2013) is a test of verbal inhibition and control (see Table 2.1, Appendix 1). It is normally used with preschool children aged 29 to 63 months (see Simpson et al., 2013 and Simpson & Carroll, 2014). In the Verbal Imitation task children must always resist prepotent verbal responding to an acoustically observed verbal stimulus. In other words, they must produce an opposite verbal response to that voiced by an experimenter. Verbal gesture response sets includes the words 'sun' and 'moon'. This response set means that when children hear the word 'sun' they must say the word 'moon', and when they hear the word 'moon' they must say the word 'sun'. Response variants in other Verbal imitation studies (e.g. Simpson et al., 2013 – Experiment 3) included 'hand', 'foot', 'dog' and 'cup'. Initial research conducted using the Verbal Imitation task with pre-schoolers

showed children were very accurate: it was very easy for children aged between 3years-old to 4-years-old to resist verbal imitation - a finding which suggests that verbal imitation is not subject to automatic activation.

2.1.4 What theories suggest verbal imitation is automatic?

In this section I consider three theories of speech perception and production: the Motor Theory of Speech Perception (Liberman, 1957), Direct Realist Theory (Fowler, 1986) and Ideomotor Theory (e.g. Greenwald, 1970). I begin by relating the main tenets of each of the three theories, and the implications of these for automaticity of verbal imitation.

The Motor Theory of Speech Perception (Liberman, 1957) proposes the motor system underlies speech perception and production. Speech perception and production is a function of interplay between oral gestures provided by a speaker and a proprioceptive feedback system utilised by observers, which guides their own speech production. In later revisions of the Motor Theory of Speech Perception (e.g. Mann & Liberman, 1983) speech perception is argued to be a phonetic module distinct from a general auditory system. As such, the Motor Theory of Speech Perception espouses a speech-as-gestures view: speech perception is achieved through the identification of others' intended articulatory, such as vocal tract, gestures (see Galantucci 2006 for a review; Lieberman & Mattingly, 1985). Notwithstanding its revisions, the Motor Theory of Speech Perception retains its position that the motor system is incorporated in the perception of speech. Consistent with this view is the proposition that perceptual and motor systems of speech are closely linked. A consequence of the motor system's role in perceiving speech is that motor representations are always activated upon speech perception: perceiving speech inevitably leads to speech motor

representations being activated. Thus, the Motor Theory of Speech Perception (e.g. Liberman and Mattingly, 1985) suggests verbal imitation is automatic.

Direct Realist Theory (Fowler, 1986) argues perception of articulatory gestures is also important to speech perception. However, in contrast to the Motor Theory of Speech Perception (e.g. Liberman & Mattingly, 1985), Direct Realist Theory refutes the importance of *intended* motor gestures to speech perception and production, in preference to *actual* gestures as the object of perception. As such, Direct Realist Theory is based on an ecological model of perception (e.g. Gibson, 1979). Applied to speech, the ecological model suggests speech sounds themselves 'give off' their structure to speech perceivers, and stimulate sense organs in observers. Under Gibson's (1979) theory direct awareness of the world occurs through sensory input that contains enough rich information for the complete recovery of the object of perception. Co-articulation, the manner in which speech sounds are affected by other speech sounds that surround them, provides a good example of the rich detail inherent in speech. The ability to recover completely the object of perception – speech – should be difficult: speech sounds are produced very rapidly and typically sounds overlap. However, full and accurate recovery of the object of perception – the words used in the speech signal – is retained in observers despite the rapid nature of speech production.

Direct Realist Theory's assumption of a direct linkage between speech perception and production is also supported by research on Mirror Neurons (e.g. Rizzolati & Arbib, 1998). Mirror Neurons fire when an observer views an action taking place and also when the observer is performing that action themselves (e.g. Rizzolatti, Fogassi & Gallese, 2002). Thus, Direct Realist Theory's suggestion that speech perception and production is linked - that

sensory input in the form of speech activates observers' motor areas involved in speech production - has a biological foundation. Given the biological basis for actual gestures of speech as the objects of perception, Direct Realist Theory (Fowler, 1986) suggests activation of the motor code for speech is an inescapable consequence of the perception of speech. As a result, knowledge of the mirror system and mirror neurons provides empirical support for automaticity of verbal imitation: the motor component required for speech production is activated upon perceiving speech. In other words, verbal imitation is automatic.

One of the guiding principles of Ideomotor theory is that representations of perception and action are shared, that a common code exists. Accordingly, perceptual events lead to the generation of actions for which the feedback is similar (for a review see Shin, Proctor and Capaldi, 2010). Simply, perception of an action effect leads to the motor representation of that action (e.g. Prinz, 1992). Applied to speech, Ideomotor Theory thus provides a straightforward account of verbal imitation automaticity. Given that the sound of speech is an action effect, the common code suggests a motor representation of speech is unavoidably activated upon its perception. Verbal imitation is, then, a predictable and inevitable product of perceiving speech. In other words, verbal imitation is arguably automatic.

2.1.5 What evidence suggests that verbal imitation is easy for children to resist?

In one of the first developmental studies of its kind Simpson et al. (2013) investigated automaticity of verbal imitation in young children. Ninety-six children aged 3 to 4-years-old took part in four SRC tasks: a novel Verbal imitation task that required children to resist verbally imitating an experimenter's spoken word (e.g. hear 'sun' say 'moon', hear 'moon' say 'sun'); an Action imitation task, the Hand Game, which required children to avoid imitating

the experimenter's manual gesture (e.g. see |finger| make a fist, see |fist| point a finger); a Naming task, the Day-Night task (Gerstadt et al., 1994), in which children had to resist naming visual stimuli (e.g. see |sun| say 'moon', see |moon| say 'sun'); and a Pointing task, the Grass/Snow task (e.g. Simpson & Riggs, 2009), in which children resist pointing to a named stimulus (e.g. hear 'sun' point to |moon|, hear 'moon' point to |sun|). Surprisingly, Simpson and colleagues (2013) found children were very accurate on the Verbal imitation task, and less accurate on the three remaining tasks – a finding which suggests that verbal imitation is subject to less automatic activation than manual imitation.

In a follow-up experiment (Simpson et al., 2013 – Experiment 2) forty-eight preschoolers took part in two Verbal imitation tasks: a Word imitation task in which children had to resist imitating a familiar word (e.g. hear 'sun' say 'moon', hear 'moon' say 'sun'), and a Non-Word imitation task in which children had to resist imitating non-words (e.g. hear 'bab' say 'mim', hear 'mim' say 'bab'). Children also took part in one Action imitation task, the Hand Game, which required children to resist imitating the experimenter's manual gesture (e.g. see |finger| make a fist, see |fist| point a finger). Results showed better accuracy on Verbal imitation tasks than the Manual imitation task. Moreover, it didn't matter if the Verbal imitation tasks used familiar words (e.g. sun or moon) or non-words (e.g. bab or mim), children had little difficulty resisting word imitation regardless of a word's veracity: Verbal imitation was easy to resist.

In Experiment 3 Simpson et al. (2013) investigated whether children were employing a delaying strategy to improve performance in the Verbal imitation task. Evidence consistent with verbal imitation being automatic in adults (e.g. D'Ausilio et al., 2009) suggested the

disparity between manual and verbal imitation observed by Simpson and colleagues (2013 – Experiments 1 and 2) may be a function of the rate of development of automaticity. If verbal imitation is automatic in adults and not young children, it might be that this automaticity develops during childhood, in which case it might be that the Verbal imitation task will actually get harder as children get older. Therefore, Experiment 3 tested 5, 7- and 11-year-olds.

Experiment 3 had ninety-six children take part in four SRC imitation tasks: two Verbal tasks (Same-Set and Different-Set) and two Manual tasks (Same-Set and Different-Set). Same-Set conditions have higher inhibitory demands than Different-Set conditions, so if the two conditions are equally difficult then the inhibitory demands are low. The Same-Set verbal imitation task used stimuli 'hear 'sun' say 'moon' hear 'moon' say 'sun'; the Different-Set verbal imitation task used stimuli 'hear 'hand' say 'foot' hear 'dog' say 'cat'. In the Same-Set manual imitation task children had to resist imitating an experimenter's manual action (see |finger| make a fist see |fist| point a finger); and in the Different-Set task manual imitation task they used (see |thumbs-up| make scissors see |hand-up| turn hand down). Accuracy and reaction time were the two dependent measurements. Results showed the verbal imitation in the Same-Set condition was not harder than in the Different-Set condition, whereas for the manual imitation condition, the Same-Set condition was harder. These data suggested that, even for older children, the inhibitory demands of the verbal imitation task were lower than the manual imitation task.

To further investigate automaticity in verbal imitation tasks, Simpson and Carroll (2014) tested three hypotheses to explain children's ease with resisting verbal imitation. The

Response Modality hypothesis suggests performance is a function of the mode of responding: manual responses are more automatic than are verbal responses. Under this hypothesis performance on Verbal imitation tasks should be better than performance on Manual imitation tasks. The Stimulus Modality hypothesis refers to the nature of the stimulus. An auditory stimulus is proposed to lead to less activation of associated representations than would a visual stimulus. Inhibiting responses to auditory stimuli is easier than inhibiting responses to manual stimuli. Under this hypothesis children should perform better when task stimuli are auditory rather than visual. The Specific Relation hypothesis refers to the relation between the stimulus and response: the mapping between perceptual and motor representations. Under the specific relation hypothesis, the *combination* of an auditory stimulus and a verbal response is argued to be easy for children to inhibit, and so children should perform better on Verbal imitation tasks than other types of SRC task.

Simpson and Carroll (2014 – Experiment 1) first tested whether avoiding verbal responding is easier than avoiding manual responding (the Response Modality hypothesis). Four tasks were used: two required verbal responses (e.g., hear 'phone' say 'cup' hear 'cup' say 'phone' and see phone say 'cup', see cup say 'phone') and two required manual responses (e.g. see |fist| make a pointed finger, see |finger| make a fist, and pick up phone make |cup action|, pick up cup, make |phone action|. They found verbal imitation is easy for children to resist on Auditory-Verbal (hear 'phone' say 'cup') tasks, but verbal and manual responses were harder to resist on each of the three remaining tasks. As a consequence, the data suggested the mode of responding did not make it easier for children to resist verbal imitation.

Simpson and Carroll (2014 – Experiment 2) next investigated whether responses to auditory stimuli or visual stimuli are easier to resist (the Stimulus Modality hypothesis). Four tasks were

used: two required verbal responses – Auditory-Verbal (e.g., hear 'phone' say 'cup', hear 'cup' say 'phone'), and Auditory-Artefact (e.g. hear 'phone' make |cup action|, hear 'cup' make |phone action|); and two required manual responses – Visual-Manual (e.g. see |fist| make a pointed finger, see |finger| make a fist), and Visual-Artefact (e.g. see phone picture make |cup action|, see cup picture, make |phone action|). Results showed it is not simply that both auditory tasks were easier than the visual tasks. Indeed, in only one verbal task – the Auditory-Verbal task - was it easier for children to resist imitative responses. Had it been that in both auditory tasks – Auditory-Verbal and Auditory-Artefact – that it was easy to suppress conflicting responses, the Stimulus Modality hypothesis would have accounted for the findings. However, in only one Verbal task was it easy for children to resist verbal imitation. This suggests visual stimuli do not lead to more automatic activation than auditory stimuli. Therefore, if it is not the Stimulus Modality hypothesis either then it must be the Specific Relation hypothesis that explains children's ease with resisting verbal imitation. It is the Specific Relation between the stimulus and response: a verbal stimulus paired with a verbal response.

2.1.6 What evidence suggests that verbal Imitation is hard for adults to resist?

Evidence suggesting that adults experience automatic verbal imitation (Dijksterhuis & Bargh, 2001; Fowler, Brown, Sabadini & Weihing, 2003; Porter & Castellaños, 1980; Porter & Lubker, 1980) is intriguing. Fowler et al. (2003), for example, showed adults have difficulty producing conflicting verbal responses during speech tests. They found reaction times were a little longer when they were asked to provide an incompatible verbal shadowing response 'ta' or 'ka' to the verbal stimuli 'pa', as opposed to a compatible response of 'pa'. Fowler and colleagues interpreted this finding as evidence that percepts of speech activate motor

components for producing speech: motor representations of speech have been activated and IC is required to suppress voicing that representation as a verbal response. In other words, suppressing verbal imitation requires inhibition. Simply, for adults at least, verbal imitation seems to be automatic.

Neurological techniques used with adults, such as Transcranial Magnetic Stimulation, provide empirical support for the involvement of the motor cortex in speech perception and production (see Mottonen and Watkins, 2012 for a short review; D'Ausilio et al. (2009); Fadiga et al. 2001; Pulvermuller, Huss, Kherif, Moscoso del Prado, Martin, Hauk, & Shtyrov, 2006; Watkins, Strafella & Paus, 2003; Wilson, Saygin, Sereno & Iacoboni, 2004). D'Ausilio and colleagues (2009), for example, used Transcranial Magnetic Stimulation to investigate the contributions of motor-articulatory systems to perceiving speech sounds. Using a phoneme discrimination task, they found participants were faster to recognise lip produced phonemes when the corresponding lip motor area was stimulated. Stimulation of a different motor area (i.e. tongue) made recognition of lip areas slower. As the authors suggest, the results imply the motor cortex has a functional role in the perception of speech: motor activity supports speech perception. That this is so, verbal imitation is arguably automatic in adults.

Mottonen, Dutton & Watkins (2013) arguably provide the most convincing neuro-psychological evidence that the motor cortex is recruited in the perception of speech. They investigated whether the motor cortex contributed to *incidental* discrimination of speech sounds (e.g. 'ba', 'ga' and 'da') and non-speech sounds (piano tones). Using electroencephalography to record electrical activity of the brain, Mottonen and colleagues recorded passive responses to changes in sound sequences whilst participants watched a

silent film. Concurrently, Transcranial Magnetic Stimulation was used to disrupt lip or hand representations in the left motor cortex. They found disruption to lip motor representations did impair perception of speech sounds but not piano tones. Additionally, disruption of the hand motor representation did not have any effect on responses to changes in speech sounds. Mottonen and colleagues' results are important as they strongly suggest that the articulatory motor cortex *is* involved in the discrimination of speech sounds. Moreover, because participants were passive responders rather than active engagers with the stimuli, the results also provide convincing evidence that hearing speech automatically activates motor representations of speech. In other words, verbal imitation is automatic.

2.1.7 Interpreting children's ease with resisting verbal imitation.

Children's ease with resisting verbal imitation is particularly interesting given evidence that adults seem to need IC to resist it. Children's verbal imitation performance is dissimilar to that of adults (e.g. Fowler et al., 2003); for adults, at least, verbal imitation *is* automatic. In this section I suggest two ways in which this developmental difference can be interpreted: either there is a problem with the tasks used in studies of children's verbal imitation, or the complexity of words impacts on performance (Simpson et al., 2013; Simpson & Carroll, 2014).

A first explanation for children's ease with resisting verbal imitation relates to the tasks used in research studies. Data from SRC tasks suggest that verbal imitation isn't automatic in 11-year-olds (e.g. Simpson et al., 2013 – Experiment 3). In this experiment the authors tested whether differences between verbal and action imitation were due to the rate at which automaticity develops. They used four tasks: two Verbal (Same-Set – 'hear 'sun' say 'moon', hear 'moon' say 'sun'; and Different-Set - hear 'hand' say 'foot', hear 'foot' say 'hand') and

two Action (Same-Set – see |finger| make a fist, see |fist| point a finger; and Different-Set – see |thumbs up| make scissors, see |hand up| turn hand down). They hypothesised that if verbal imitation is automatic then a Response Set Effect would be observed. However, the results showed no Response Set Effect for 11-year-olds. To countenance this finding Simpson and colleagues explained that verbal imitation could still be automatic, but that the difficulty of the Different-Set condition masked any Response Set Effect. Alternatively, it is suggested that automaticity of verbal imitation manifests in older children. However, it seems unlikely that if verbal imitation is not automatic after 11-years-old that it will become automatic later. Therefore, if verbal imitation is automatic in 11-year-olds then there must be a problem with the task that means - despite verbal imitation being automatic - children don't have to use IC when performing on it.

A second explanation for children's apparent ease with resisting verbal imitation relates to the verbal stimuli used in the tasks. For Simpson and colleagues (2013), Word stimuli are easier to resist imitating than Manual stimuli due to words' inherent complexity. Under a Complexity account (Simpson and Carroll, 2014; Simpson et al., 2013) the complex arrangement of phonemes within words ultimately impacts on automaticity. In contrast to Manual stimuli, which are single gestures, words are comprised of a precise series of gestures produced at high speed: it is this complexity of words that ultimately leads to a 'slow mapping' (Simpson et al., 2013) between speech perception and speech motor representations. Speech motor representations are not activated, or are activated very little, when perceiving speech. Thus, *word* imitation is not automatic, because the complexity of words interferes with the mapping between perceptual and motor representations. In contrast, manual imitation is automatic in children because simple stimuli and response are used in Manual imitation tasks.

2.1.8 The studies in this chapter

The three experiments in Chapter 2 built on research with young children that showed performance differences in Verbal and Manual imitation tasks (Simpson et al., 2013; Simpson & Carroll, 2014). I explored whether verbal imitation was always easier for young children to resist imitating than manual imitation. Developing the research findings of Simpson and colleagues, I investigated the hypothesis that children's ease with resisting verbal imitation was due to the complexity of the word stimuli used in verbal imitation tasks. The Complexity account (Simpson et al. 2013; Simpson & Carroll, 2014) suggests words' complexity leads to a 'slow mapping' between speech perception and production representations. As a consequence of 'slow mapping' speech motor representations are not activated, or are activated very little, when perceiving speech. A Complexity account therefore predicts that the imitation of simpler verbal stimuli would be as difficult to resist as manual imitation.

In Experiment 1, I investigated the Complexity account. I used three Verbal imitation tasks: Word (e.g. hear 'dog' say 'cup', hear 'cup' say 'dog'), Syllable (e.g. hear 'woo' say 'boo', hear 'boo' say 'woo'), and Vowel (e.g. hear 'Ooo' say 'Eee', hear 'Eee' say 'Ooo'); and one Manual imitation task, the Hand Game (e.g. see |finger| make a fist, see |fist| make a pointed finger). Based on the Complexity account, I hypothesised that verbal imitation is only easier than manual imitation when the verbal stimuli are more complex. I predicted the Syllable and Vowel conditions would be as difficult as the Manual condition. Experiment 1 showed children were *not* more accurate on any of the Verbal conditions than on the Manual imitation task: children struggled with all four tasks. The data were not consistent with a Complexity account of verbal imitation: Syllable and Vowel conditions were not more difficult than the Word task. Furthermore, I failed to replicate the previous finding that verbal

imitation *with words* was easier to resist than manual imitation (Simpson et al., 2013; Simpson & Carroll, 2014).

I speculated that children might have performed poorly on all the verbal imitation tasks in Experiment 1 because they struggled to remember the task rules. If children can't remember the rules then they will fail the task, irrespective of its inhibitory demands. As such, the procedure to teach children the task's rules was revised in Experiment 2a. In Experiment 2a, I used two Verbal imitation tasks: Word (e.g. hear 'dog' say 'cup', hear 'cup' say 'dog') and Syllable (e.g. hear 'woo' say 'boo', hear 'boo' say 'woo'); and one Manual imitation SRC task, the Hand Game (e.g. see |finger| make a fist, see |fist| make a pointed finger). Based on the Complexity account, I again hypothesised that verbal imitation is only easier than manual imitation when the stimulus is more complex. Thus, I predicted the Syllable condition would be as difficult as the Manual condition. I did observe that the Word condition was easier than the Manual imitation task (replicating previous findings). However, the results also showed that accuracy on Word and Syllable conditions was similar, and therefore did not support the Complexity account.

I again speculated that comparable performance on Word and Syllable conditions might be due in part to children's difficulty with learning SRC task rules. I addressed this concern in Experiment 2b by introducing a mandatory practice session, which children had to pass prior to the testing session. I was also concerned that the inhibitory demands of the SRC tasks might have been reduced because of the relatively short test session used in Experiment 2a (12 trials in each task). I therefore increased the length of the test session (to 20 per task). Experiment 2b used three SRC tasks; two Verbal imitation: Word (e.g. hear 'dog' say 'cup',

hear ‘cup’ say ‘dog’) and Syllable (e.g. hear ‘woo’ say ‘boo’, hear ‘boo’ say ‘woo’); and one Manual imitation, the Hand Game (e.g. see |finger| make a fist, see |fist| make a pointed finger). I again hypothesised that verbal imitation is only easier than manual imitation when the stimulus is more complex. I predicted the Syllable condition would be as difficult as the Manual condition. The result of Experiment 2b supported the Complexity hypothesis: word imitation was easier to resist than syllable imitation.

2.2 Experiment 1

2.2.1. Introduction

Experiment 1 tested a Complexity account of resisting verbal imitation (Simpson & Carroll, 2014). Under a Complexity account, children find words are easier to resist imitating than syllables and vowels because words are more complex. Experiment 1 tested verbal and manual imitation in four SRC tasks using an *if-A-then-B/if-B-then-A* rule structure: one Manual imitation SRC task (Hand game) and three Verbal imitation tasks (Word, Syllable and Vowel conditions). Table 2.2 shows the rules used in the four SRC conditions. I hypothesised that resisting verbal imitation is only easier than resisting manual imitation when the verbal stimuli are more complex. I predicted that the Syllable and Vowel conditions would both be as difficult as the Manual condition; while the Word condition would be easier than the Manual condition.

SRC Task	Response
Manual Imitation	See |Finger| make fist, see |Fist| point finger
Word Imitation	Hear 'Dog' say 'cup', hear 'cup' say 'dog'
Syllable Imitation	Hear 'Woo' say 'Boo', hear 'Boo' say 'Woo'
Vowel Imitation	Hear 'Ooo' say 'Eee', hear 'Eee' say 'Ooo'

Table 2.2. The four SRC tasks used in Experiment 1.

2.2.2 Methods

Participants

Study participants (N = 27; nine female) consisted of young children aged between 36 and 48 months old (mean age = 41 months). Children were recruited from two nursery schools located in a mid-sized town in a semi-rural county in the East of England. All children spoke English as their first language. No children were reported to have any learning or educational problems.

Design

A within-participants design was used. Stimulus type (Manual, Word, Syllable, Vowel) was the independent variable. Participant accuracy on the 16 test trials was the dependent variable.

Materials

A researcher-devised chart was used to record the accuracy of participant responses. Test sessions were also audio-recorded using Audacity software and in-built microphone equipment on an Apple Macbook Pro laptop computer.

Procedure

SRC tasks consisting of an *if-A-then-B/if-B-then-A* rule structure were employed (see Table 2.2). The Manual imitation task used the rules: see |finger| make a fist, see |fist| point a finger. The Word imitation task used the same rules but with verbal stimuli and responses 'Dog' and 'Cup'. For the Syllable imitation task the syllables 'Woo' and 'Boo' were employed. For the Vowel imitation task 'Ooo' and 'Eee' were used. Each task comprised four practice trials (order ABAB) and 16 test trials in a predetermined pseudorandom order (ABBABAAB BABAABAB). Children completed the four practice trials before beginning the test trials.

Children completed two test sessions of approximately 10 minutes each in duration on two different days. The sessions were not more than 10 days apart. The Manual imitation task and Syllable imitation task were tested in one session. The Word imitation task and Vowel imitation task were tested in the other session. Session order and the order of the two tasks within session were counterbalanced across participants, which produced four orders overall. Prior to beginning the tasks, children were collected from the main nursery room by a nursery employee and brought to the test room where the experimenter was seated. The experimenter introduced himself and invited the child to sit opposite him at a low table. All children were accompanied by a nursery employee who was seated close by, but who was instructed not to help children during the testing.

On beginning the experiment, the experimenter explained he was at the nursery to play some 'silly games' with the children. Each child was asked if they wanted to take part. Children were asked to show that they could make the verbal or manual gestures required to play the game. For example, in the Manual imitation task the experimenter made a fist with his hand and asked the child to show they too could make a fist with their hand. The experimenter then pointed his finger, and asked the child to show they could also make this gesture with their own hand. Similarly, in the Vowel task children were asked to demonstrate they could say 'Eee' and 'Ooo'; in the Syllable task 'boo' and 'woo'; and in the Word task, 'dog' and 'cup'. Children who were unable to make the correct verbal or manual gesture were corrected on pronunciation or physical gesture.

The rules of the game were then described to the child. For example, in the Vowel imitation SRC task the experimenter explained, 'when I say 'Ooo' you must say 'Eee', and when I say 'Eee' you must say 'Ooo'. In addition, explanation of game rules for the Verbal tasks were accompanied by the experimenter using his finger to point to his own mouth or the child's mouth to reinforce the response that should be provided by the child in reply to the experimenter's preceding verbal gesture. For the Manual imitation task the experimenter explained 'when I make a fist with my hand, you must point your finger, and when I point my finger you must make a fist'. During explanation of the Manual imitation task rules, the experimenter also demonstrated the fist and finger pointing actions with one hand, whilst using his other hand to point to himself or the child to reinforce the response that should be provided by the child. To confirm children had understood the instructions they were then asked if they remembered what to do in the task. Participants who remained unsure of the response that they should provide were again informed of the game rules. Once the

experimenter had received confirmation that the child understood the rules of the game the experiment began with four practice trials.

During practice trials participants were provided with feedback; the experimenter corrected incorrect responses and confirmed correct responses. For example, in the Vowel Task practice trials if the child responded 'Eee' to 'Ooo' the experimenter confirmed the response was correct by way of saying 'well done' or 'good'; however, if the child responded 'Ooo' to 'Ooo' the experimenter identified the response as incorrect and provided the correct response; children were reminded 'when I say 'Ooo' you must say 'Eee', and when I say 'Eee' you must say 'Ooo'. Upon completion of the four practice trials children were then invited to play the game 'for real' and told that they would receive a sticker at the end of the game.

Prior to playing the game 'for real' the experimenter informed the child one final time of the game rules by saying, e.g. in the Vowel task, 'Now, remember, when I say 'Ooo' you must say 'Eee', and when I say 'Eee' you must say 'Ooo'. Verbal disclosure of task instructions was once again accompanied by the experimenter physically pointing to the child's mouth and to his own mouth to reinforce which response the child should provide in reply to the experimenter's verbal gesture. In the Manual task children were once again shown the hand and pointing gestures they were required to make, whilst the experimenter used his other hand to point to himself or the child to reinforce the response the child should provide. The test trails then began.

During test trials no feedback was provided, only a confirmatory reaction to the child's response. Upon completion of the 16 test trials children were told that they had played a

good game and were invited to pick a sticker of their choosing to keep. At the end of the first game in each session participants were then invited to play another 'silly game' for which they would receive another sticker. At the end, the second game in each session children picked a sticker, were thanked by the experimenter for taking part, and were then returned to the main play room by the nursery school employee.

2.2.3 Results

I begin by providing a summary of accuracy across each of the SRC tasks. I then analyse accuracy by Stimulus Type, Gender, Task order, and performance across test trials. Total correct responses were summed for each SRC task and converted to a percentage. Overall, accuracy in each of the four SRC tasks was poor, and ranged from 36% to 49%. Participant accuracy was similar in each of the four imitation SRC tasks (see Fig 2.1).

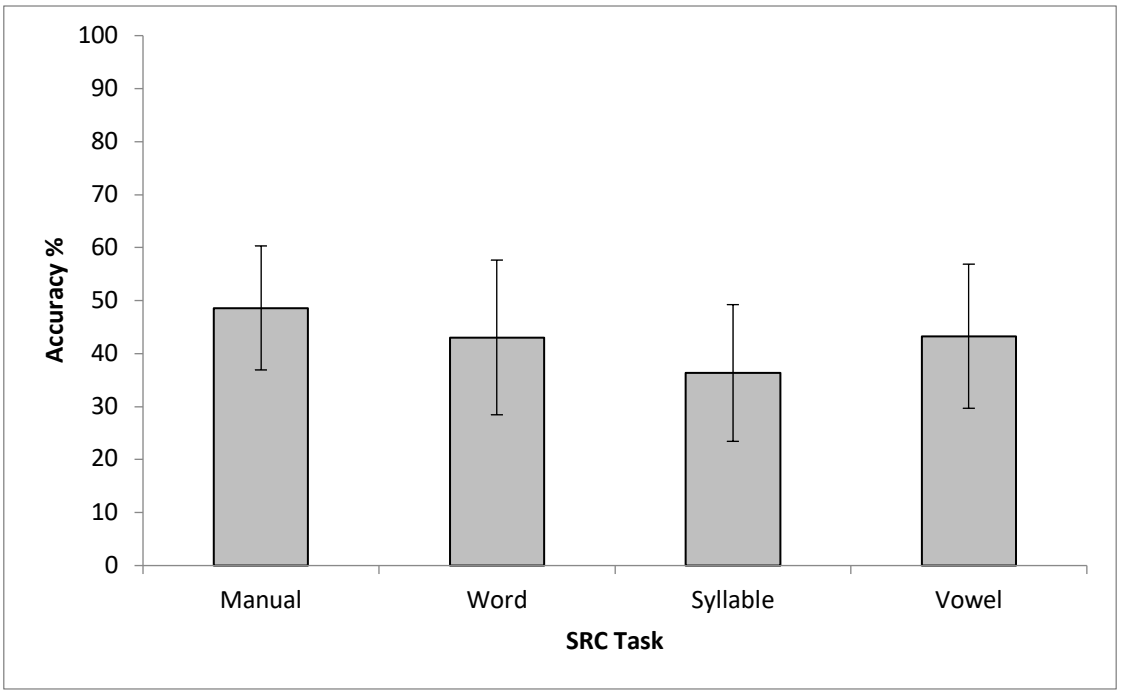


Figure 2.1. Percentage accuracy of four SRC tasks including SEM error bars in Experiment 1.

First analysis of SRC data investigated differences between Stimulus Type. Mauchly's test indicated assumptions of sphericity had been violated, $\chi^2(5)=23.11, p<0.01$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .63$). A one way repeated measures ANOVA showed no statistically significant difference between the SRC Tasks $F(1,49) = 2.13$, $p = .13$, $\eta_P^2 = .08$.

Further analysis of SRC data investigated effects of gender. The data were analysed using a mixed ANOVA with SRC task (Manual, Word, Syllable, Vowel) as the within-participants factor and Gender (Male, Female) as the between participants factor. Mauchly's test indicated assumptions of sphericity had been violated $\chi^2(5)=21.89, p<0.01$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .63$). There was no significant main effect of SRC task $F(1.89, 47.3)=1.59, p=.22$, $\eta_P^2=.06$. There was no difference in accuracy between each of the four SRC tasks. There was also no main effect of gender $F(1,25)=.04, p=.85$, $\eta_P^2=.001$ indicating there was no difference between male and female's accuracy on each of the four SRC tasks (see Fig 2.2). There was no significant interaction between SRC task and gender $F(1.89,47.3)=.46, p=.62$, $\eta_P^2=.02$.

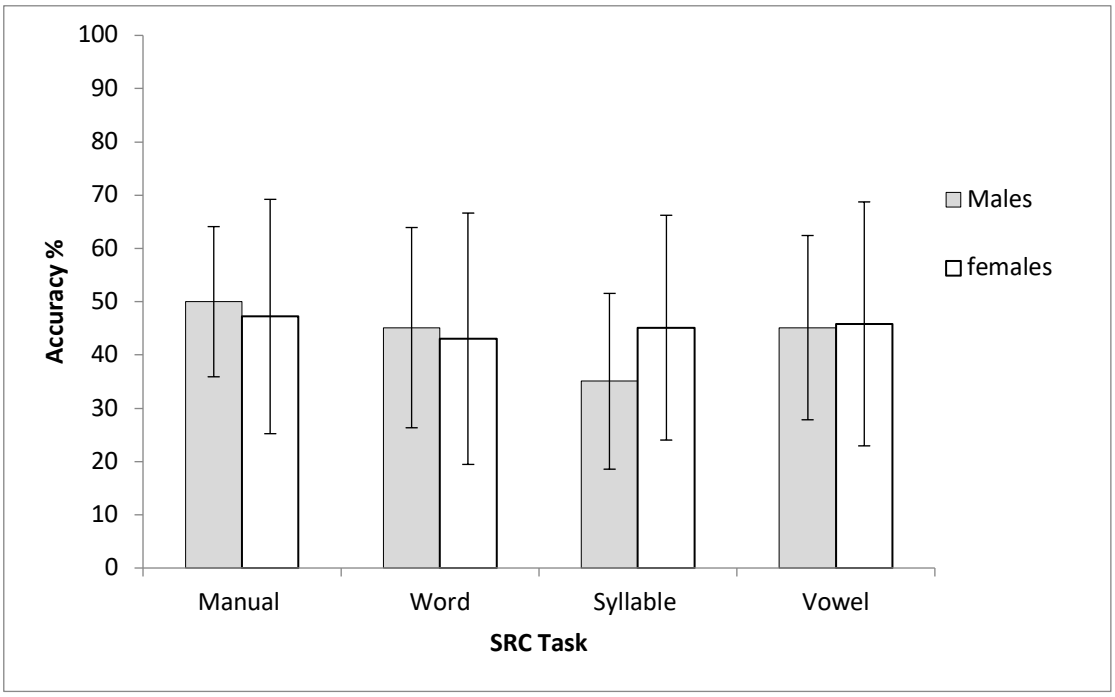
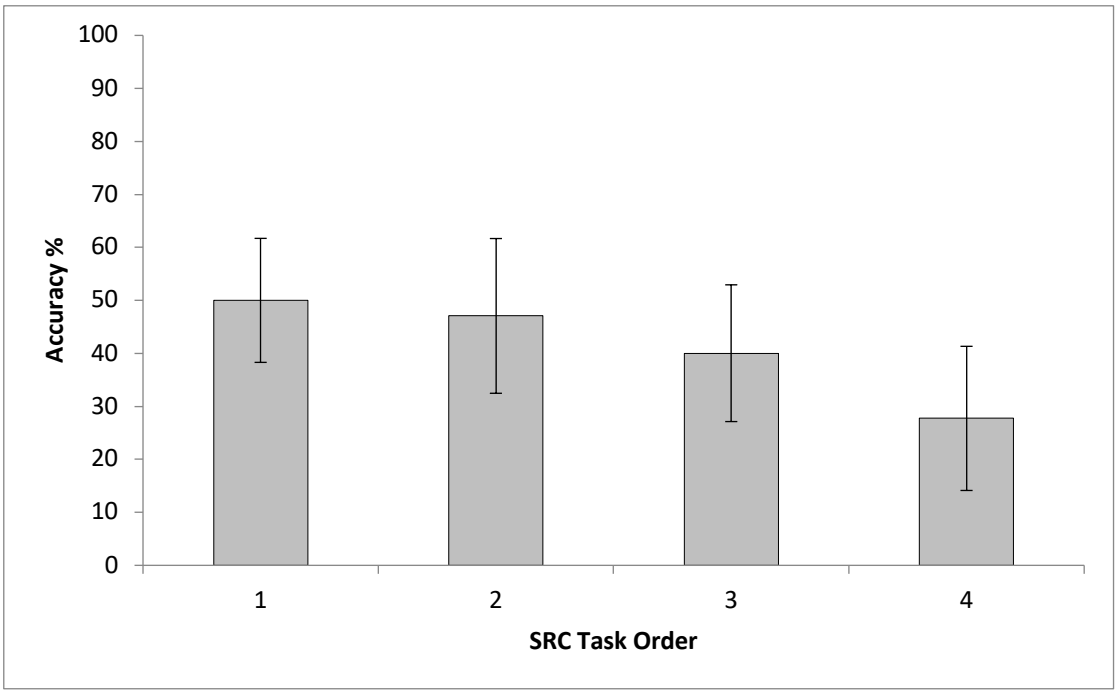


Figure 2.2. Male and Female accuracy on four SRC tasks including SEM error bars in Experiment 1.

Further analysis of SRC data investigated whether the order imitation SRC tasks were presented to participants affected SRC imitation task accuracy (see Fig 2.3). I coded each condition based on its order of presentation 1 – MSWV; 2 –WVMS; 3 – SMVW; 4 – VWSM. Mauchly's test indicated assumptions of sphericity had been violated, $\chi^2(5)=19.66, p<0.01$ therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε =.63). Linear analysis indicated that there was no significant trend in the data F(1, 23)=3.69, p=.07, η_P^2=.14. There was also no significant main effect of SRC task order F(3,23)=.28,p=.84, η_P^2=.03. There was no significant interaction between SRC task order and SRC task performance F(5.63,43.2)=1.46,p=.21,η_P^2=.16. There is no difference between the order in which SRC tasks are completed and children's performance on SRC tasks.



F**igure 2.3**. Percentage accuracy of four SRC tasks per SRC task order including SEM error bars in Experiment 1.

Previous research shows children's performance decreases across trials: accuracy is better on trials that appear earlier in the task than those that appear later. To investigate SRC trial performance across the whole task, the 16 trials in Experiment 1 were grouped to form quartiles (Trials 1-4, 5-8, 9-12, 13-16). It was expected that accuracy would deteriorate in later trials. Total correct scores were calculated per block for each SRC task and converted to form a percentage score (see Fig 2.4). Performance across blocks was not similar for each SRC task. Initial good performance in Manual imitation block one decreased as blocks progressed. Word imitation performance was initially poor in block one but increased across blocks two and three before decreasing in block four. Vowel imitation performance increased from block one to block two but decreased in block three before levelling off in block four. Syllable imitation performance across blocks was worst out of all SRC tasks. Syllable imitation increased from block one to block two, but decreased in blocks three and four. The data were analysed using

a two way repeated measures ANOVA with SRC task (Manual, Word, Syllable, Vowel) and blocks (1,2,3,4) as factors. There was no significant main effect of blocks F(2.09,54.5)=1.45,p=.24, η_P^2=.05 and no interaction between SRC tasks and blocks F(5.13,133.6)=.80,p=.55, η_P^2=.03.

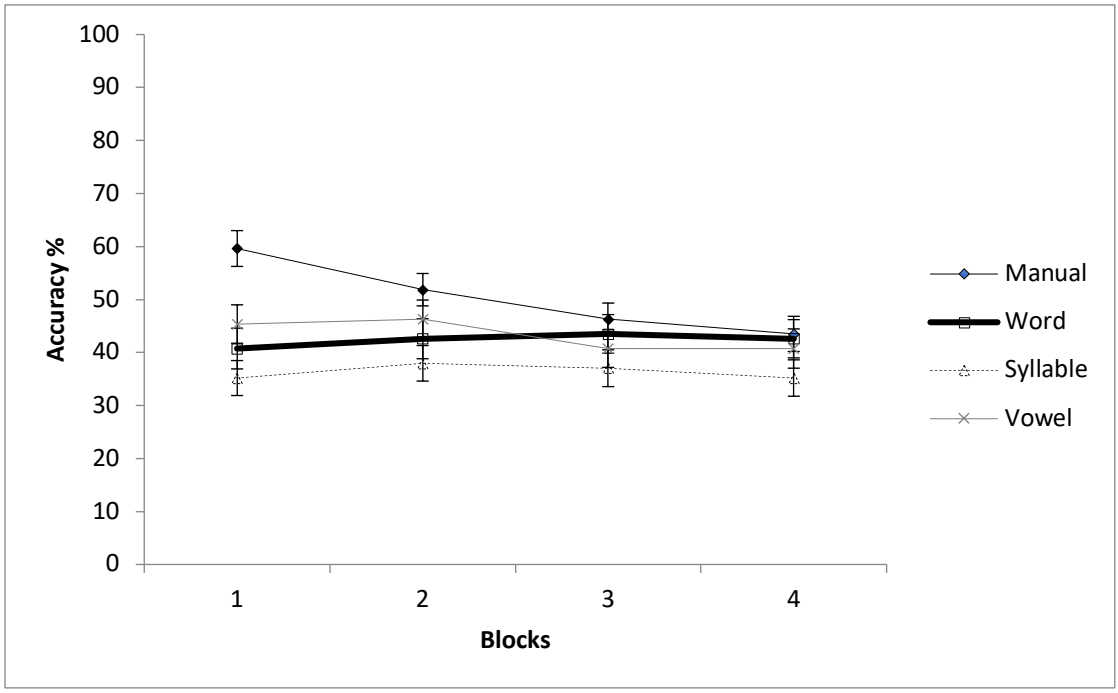


Figure 2.4. SRC imitation task performance across four blocks including SEM error bars in Experiment 1.

2.2.4. Discussion

Experiment 1 used four SRC tasks: three requiring children to resist verbal imitation (Word, Syllable and Vowel), and one to resist manual imitation (Hand Game). Statistical analysis of data in Experiment 1 showed two striking results: children did not find word imitation easier to resist than manual imitation, and in fact there were no differences in accuracy between any of the four tasks.

The data from Experiment 1 were not consistent with previous research that shows word imitation is easier to resist than manual imitation (Simpson et al. 2013; Simpson & Carroll, 2014). Furthermore, Experiment 1 data were not consistent with the Complexity account of resisting verbal imitation (e.g. Simpson et al., 2013; Simpson & Carroll, 2014). Under the Complexity account, words' complexity produces a 'slow mapping' between perception and production representations, and consequently, word imitation should be easier to resist than syllables and vowels imitation. However, Experiment 1 data showed children were not more accurate on the Word condition than the Syllable and Vowel conditions.

Experiment 1 produced performance close to 50%, a result consistent with responding at chance levels, across all four tasks. I speculated that children were failing to learn the rules in the verbal imitation tasks. Previously, Simpson and colleagues (2013) have suggested that children have particular difficulty in learning the rules used in these tasks, in which they must remember arbitrary associations between word pairs (e.g., to say "cup" to the word "dog'). It might be that children struggled in the current experiment, because they were required to remember arbitrary associations between *three* pairs of rules (in the Word, Syllable and Vowel conditions). Thus, I concluded it was premature to reject the Complexity account, of why children find word imitation easy to resist, on the basis of data from Experiment 1. It was possible data would be obtained to support the Complexity account, if children were helped to learn the task rules of the verbal conditions.

2.3 Experiment 2a

2.3.1 Introduction

Experiment 1 investigated verbal and manual imitation in SRC tasks. The results showed children were not more accurate at resisting word imitation than manual imitation, and were therefore not consistent with previous data (e.g. Simpson et al., 2013). Experiment 1 results were also not consistent with the Complexity account of what makes verbal imitation easy to resist. Children were not more accurate at resisting *word* imitation than syllable or vowel imitation. However, poor performance on all verbal imitation tasks in Experiment 1 might be explained by children's inability to acquire the task rules; if children cannot initially learn the rules of the SRC task, than IC is not being tested at all.

Experiment 2a addressed the rule acquisition concerns raised in Experiment 1. I revised the process by which children were taught the task rules: children's stimuli and response learning was scaffolded. Prior to beginning SRC tasks in Experiment 2a children were asked to show that they could make the manual or verbal gesture required. Once the child had successfully demonstrated the required verbal or manual gesture, the experimenter and child practiced repeating the gesture. A mixed design was used so that each child only had to learn one set of verbal condition rules (rather than three as in the first experiment). Furthermore, to ensure the stimuli used in this experiment were consistent with adult verbal imitation studies (e.g. Simpson et al., 2013), the Vowel imitation task was omitted.

In Experiment 2a I continued my investigation of verbal and manual imitation in SRC tasks. Three SRC imitation tasks were employed: one Manual imitation task and two Verbal imitation tasks (Word and Syllable). Table (2.3) shows the three experimental conditions. I hypothesised that verbal imitation is only easier than manual imitation when the verbal

stimuli are more complex than the manual stimuli. I predicted the Syllable condition would be as difficult as the Manual condition.

Table 2.3. The three SRC tasks used in Experiment 2a.

SRC Task	Response
Manual Imitation	See |Finger| make fist, see |Fist| point finger
Word Imitation	Hear 'Dog' say 'cup', hear 'cup' say 'dog'
Syllable Imitation	Hear 'Woo' say 'Boo', hear 'Boo' say 'Woo'

2.3.2. Methods

Participants

Study participants (N = 40; 22 female) consisted of young children aged between 36 and 51 months old (Mean age = 47.68 months). Children were recruited from nursery schools located in a mid-sized town in a semi-rural county in the East of England. All children spoke English as their first language. None were reported to have any learning or educational problems.

Design

A between subjects design was used. Stimulus type: Manual (N=40), Word (N = 20) and Syllable (N=20) was the independent variable. Two sub-groups Participant accuracy on the 12 test trials was the dependent variable.

Materials

Verbal responses were audio-recorded using the same equipment used in Experiment 1.

Procedure

SRC tasks used the same if-A-then-B/if-B-then-A rule structure and similar stimuli and responses as Experiment 1 (see Table 2.3). Each SRC imitation task comprised four practice trials (order ABAB) and 12 test trials in a pseudorandom order (ABBABAABBABA). Children took part in two sessions of approximately 10 minutes in duration across two days. Twenty children completed Manual and Word imitation SRC tasks, and twenty different children completed Manual and Syllable imitation SRC tasks. Imitation SRC tasks were counterbalanced within each group. Sessions were not more than ten days apart.

Prior to beginning the SRC tasks, children were collected from the main nursery room by a nursery employee and brought to the test room where the experimenter was seated. The experimenter introduced himself and invited the child to sit opposite him at a low table. All children were accompanied by a nursery employee who was seated close by, but who was instructed not to help children during the testing.

Before the SRC tasks began the experimenter demonstrated the manual and verbal gestures, and children were asked to show that they too could do so. Once the child had successfully demonstrated the required verbal or manual gesture the experimenter and child practiced repeating the verbal gesture aloud or practiced physically making the fist and finger pointing gesture. The rules of the game were the same as in Experiment 1 and were explained to the child by the experimenter. When the child had confirmed they understood the rules of the game, four practice trials began.

During practice trials participants were provided with feedback; the experimenter corrected incorrect responses and confirmed correct responses. For example, in the Word imitation SRC Task practice trials if the child responded 'Dog' to 'Cup' the experimenter confirmed the response was correct by way of saying 'well done' or 'good'; however, if the child responded 'Cup' to 'Cup' the experimenter identified the response as incorrect and provided the correct response; children were reminded 'when I say 'Cup' you must say 'Dog', and when I say 'Dog' you must say 'Cup'. Upon completion of the four practice trials children were then invited to play the game 'for real' and told that they would receive a sticker at the end of the game.

Prior to playing the game 'for real' the experimenter informed the child one final time of the game rules. Verbal disclosure of task instructions was once again accompanied by the experimenter physically pointing to the child's mouth and to his own mouth to reinforce which response the child should provide in reply to the experimenter's verbal gesture. In the Manual SRC Task children were once again shown the hand and pointing gestures they were required to make, whilst the experimenter used his other hand to point to himself or the child to reinforce the response the child should provide. The test trails then began.

During test trials no feedback was provided, only a confirmatory reaction to the child's response. Upon completion of the 12 test trials children were told that they had played a good game and were invited to pick a sticker of their choosing to keep. At the end of the first game in each session participants were then invited to play another 'silly game' for which they would receive another sticker. At the end, the second game in each session children picked a sticker, were thanked by the experimenter for taking part, and were then returned to the main play room by the nursery school employee.

2.3.3. Results

Total correct responses were summed for each modality (Manual, Word and Syllable) and converted to a percentage (Figure. 2.5). Accuracy in each of the three imitation SRC tasks was relatively high. Importantly, accuracy was better than in Experiment 1, and suggests that children were successful in learning the task rule. Of the three tasks in Experiment 2a, children were more accurate on the Word task than on the Manual task; and more accurate on the Syllable task than the Manual task. Overall, both verbal tasks were easier than the Manual task.

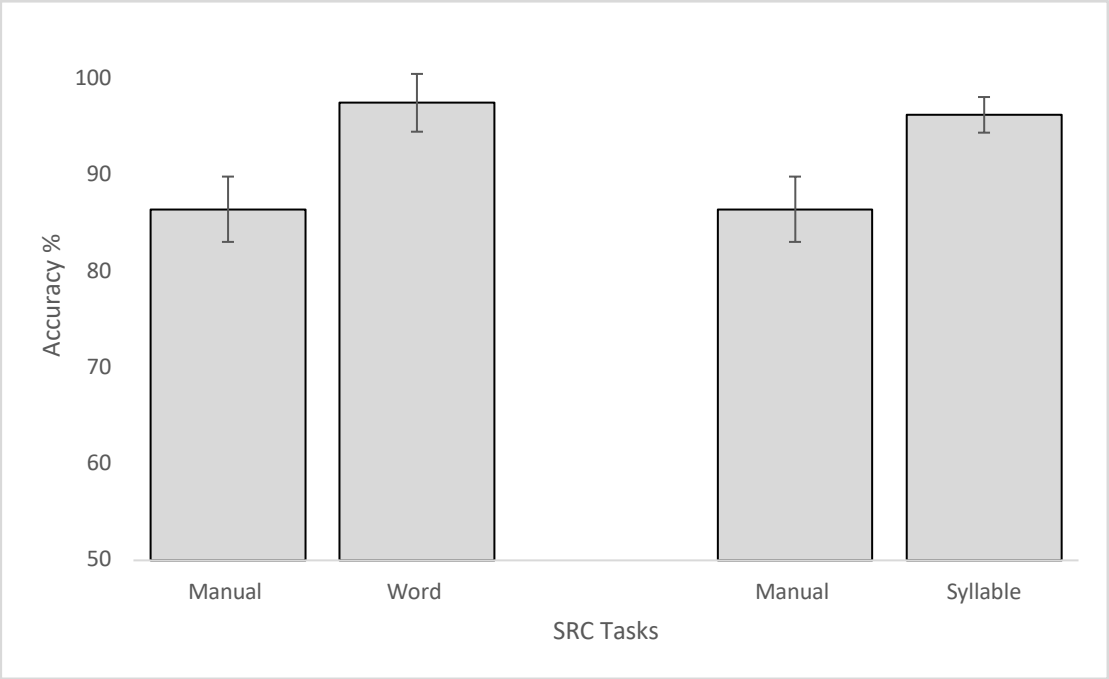


Figure 2.5. Percentage accuracy of four SRC tasks including SEM error bars in Experiment 2a.

First analysis of SRC data investigated differences between SRC tasks. Manual and Word imitation were compared in a paired samples t-test. The results showed Manual imitation was significantly different to Word imitation t(19)= -2.93, p=.009, 95% CI (4% - 23%): Word accuracy was better than Manual accuracy. Using the Cohen's d effect size convention

(Cohen, 1988), the effect size for this analysis was found to be medium-large (0.65). I then compared Manual and Syllable imitation. A paired samples t-test showed Manual imitation was not significantly different to Syllable imitation t(19)= -1.70, p=.105. Lastly, a paired samples t-test showed Word imitation was not different from Syllable imitation t(19)= .40, p=.691.

Next, I combined the Word and Syllable conditions to form a 'Verbal' modality. Total correct responses were summed for each modality (Manual, Verbal) and converted to a percentage. Overall, children's accuracy was good, with greater accuracy on Verbal imitation tasks (Figure 2.6). A paired samples t-test showed the difference between Manual and Verbal modalities was statistically significant t(39)=-3.31,p=.002, 95% CI (4% - 17%). Using the Cohen's d effect size convention, the effect size for this analysis was found to be medium (0.52).

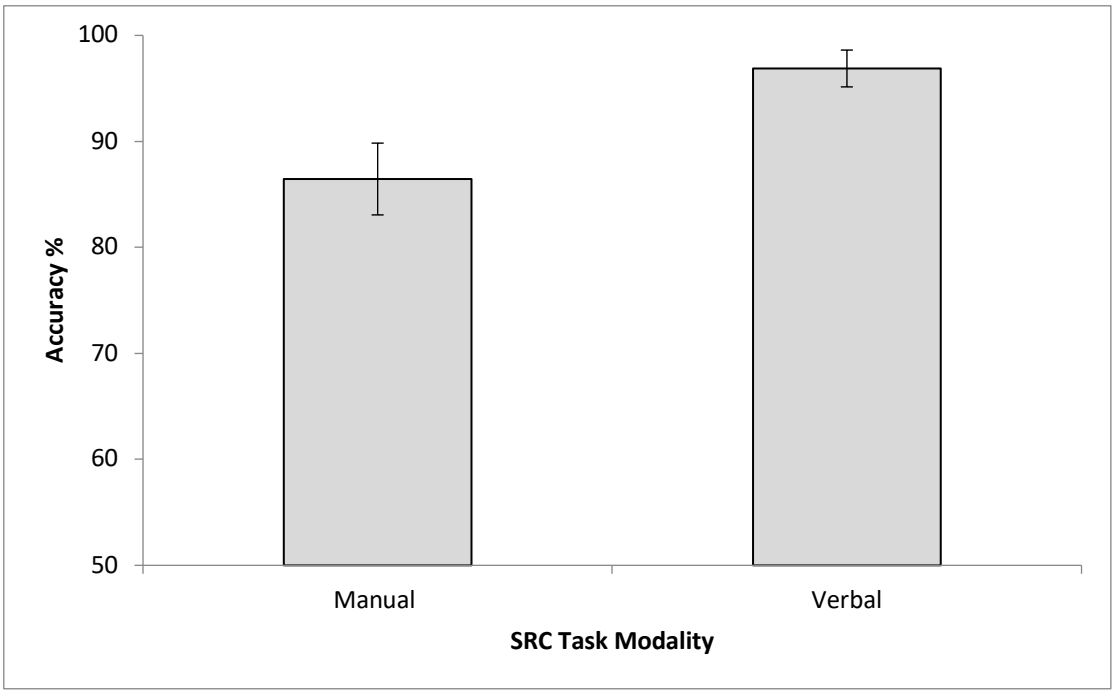


Figure 2.6. Percentage accuracy of two SRC task modalities including SEM error bars in Experiment 2a.

I then investigated for effects of gender. Data were analysed using a 2x2 mixed ANOVA with Modality (Manual, Verbal) as the within-participants factor and Gender (Male, Female) as the between-participants factor. There was a significant main effect for Modality $F(1,38)=10.4, p=.003$, suggesting a difference between children's accuracy on Manual and Verbal SRC tasks; and the effect size was small ($\eta_P^2=.21$) . There was no significant main effect of Gender $F(1,38)=.83, p=.368$, $\eta_P^2=.02$ indicating there was no difference between male and female children's accuracy on Manual and Verbal imitation tasks (see Fig 2.7). There was also no significant interaction between modality and gender $F(1,38)= .21$, $p=.647$, $\eta_P^2=.01$.

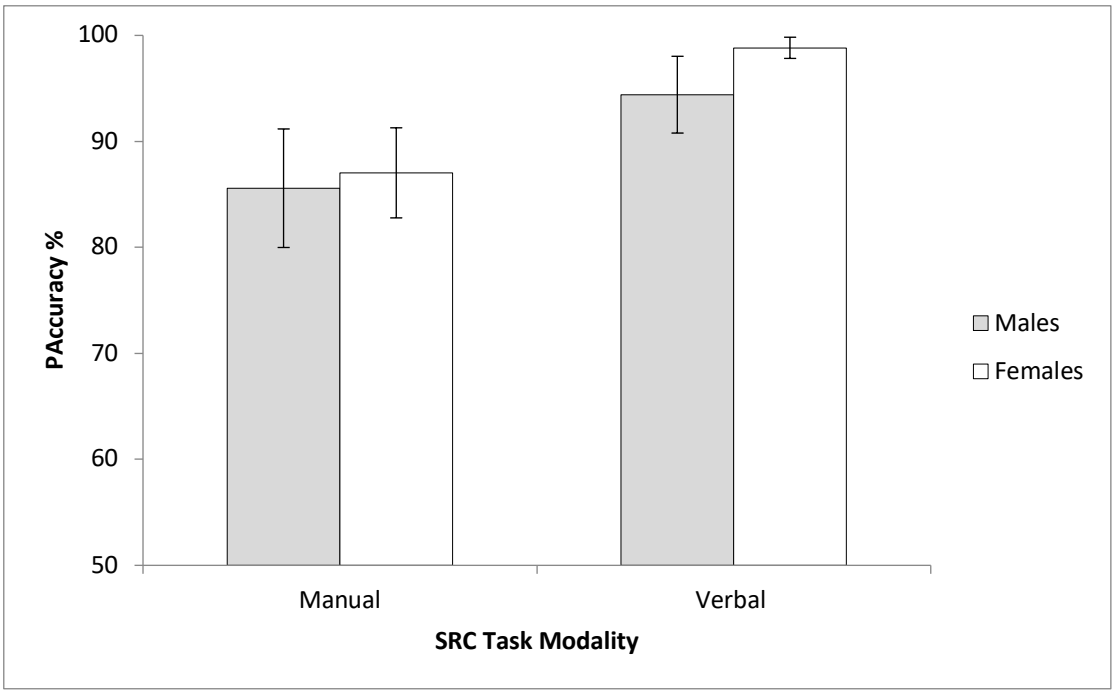


Figure 2.7. Percentage accuracy for males and females on two SRC task modalities including SEM error bars in Experiment 2a.

Previous research shows task accuracy is better on trials that appear earlier than those that appear later. To investigate SRC trial performance across the whole task, the 16 trials in Experiment 2a were grouped to form quartiles (Trials 1-4, 5-8, 9-12, 13-16). It was expected that accuracy would deteriorate in later trials. To investigate SRC performance across trials, the 12 trials were grouped into three blocks (trials 1-4, 5-8, 9-12). Total correct scores were calculated per block for each modality and converted to form a percentage score (Figure 2.8). There was a trend for poorer performance across the three blocks. The data were analysed using a two way repeated measures ANOVA with Modality (Manual, Verbal) and Blocks (1,2,3) as factors. Mauchly's test indicated assumptions of sphericity had been violated $\chi^2(2)=9.34, p<0.05$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = .82). There was a significant effect of Block $F(1.64,64)=4.16, p=.027$, $\eta_P^2=.10$ indicating performance was different between Blocks 1, 2 and

3. However, there was no interaction between Block and Modality F(2,78)=.19,p=.822, η_P^2=.005.

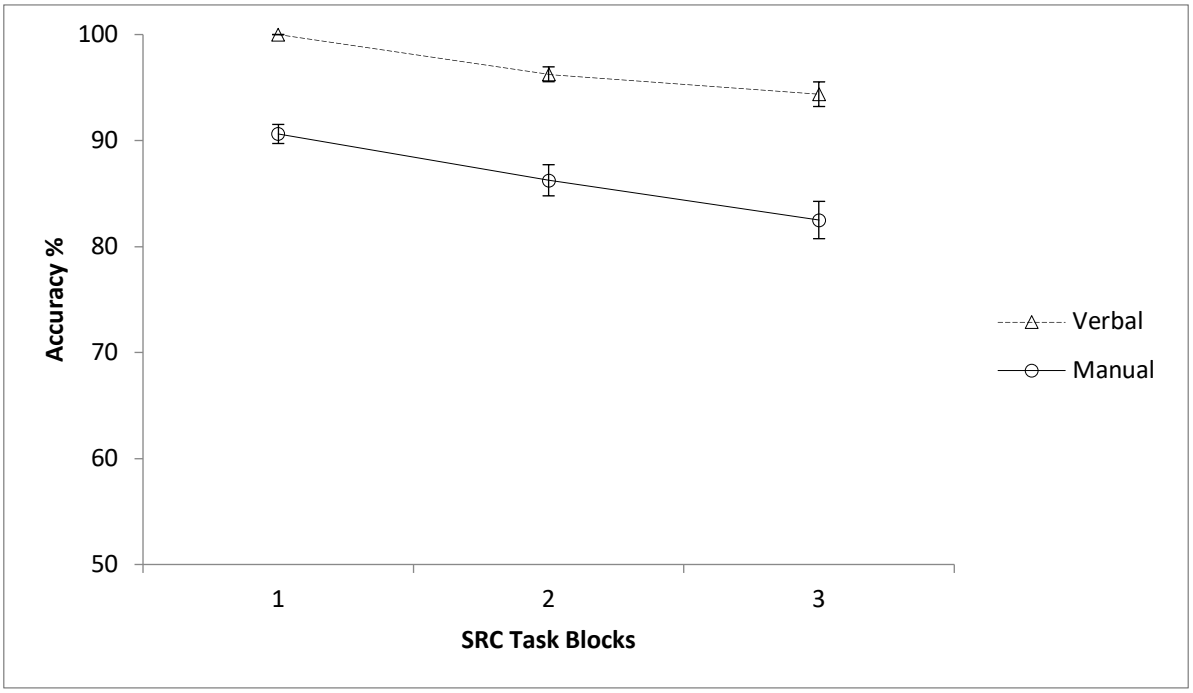


Figure 2.8. Verbal and Manual modality performance across three blocks including SEM error bars in Experiment 2a.

2.3.4. Discussion

The data showed children performed much better on all the tasks in Experiment 2a than in Experiment 1 – and suggests I was successful in helping children to learn the task rules. Furthermore, children performed better on the Word condition than on the Manual task, and this supports previous findings that show verbal imitation is easier to resist than manual imitation (Simpson et al 2013; Simpson & Carroll, 2014)**.** However, performance on the Word and Syllable conditions did not differ significantly. As such, the Complexity hypothesis was not supported.

2.4. Experiment 2b

2.4.1 Introduction

The results of Experiment 2a showed Word imitation was not easier to resist than Syllable imitation: this did not support the Complexity account. One explanation for why performance on these two tasks was not different, despite the Complexity account being valid, was due to the length of the test sessions used in the SRC tasks. In Experiment 2a children were only given 12 test trials in each task. It has previously been proposed that children's inhibitory weakness causes their performance to *deteriorate* as the task continues (Gerstadt et al., 1994; Diamond et al., 2002). Thus, it might have been that the tasks used in Experiment 2a were too short to provide an effective measure of the inhibitory demands of these SRC tasks. In Experiment 2b, the length of the test session was increased from 12 to 20 trials in an effort to increase the tasks' inhibitory demands.

In Experiment 2b I wished to return to a within-participants design, as this increased statistical power. However, I continued to be concerned about young children's ability to learn the task rules in the verbal conditions. If children did not correctly acquire the rules of the SRC tasks, then IC was not being measured when using these tasks, and the Complexity account was not being tested. Experiment 2b addressed this concern by introducing a mandatory pre-test assessment to check that children knew the rules of the task at the outset. Children had to complete three out of four (75%) practice trials successfully before beginning the test session proper. Two opportunities were allowed to pass the pre-test session.

In Experiment 2b I continued to investigate verbal and manual imitation in SRC tasks. I used three SRC imitation tasks – one Manual (Hand Game) and two Verbal (Word and Syllable) – the same as in the previous experiment (Table 2.3). I again hypothesised that verbal imitation is only easier than manual imitation when the stimulus is more complex. I predicted the Word condition would be easier than the Manual condition, but that the Syllable condition would be as difficult as the Manual condition.

2.4.2. Methods

Participants

Study participants (N =27; 15 female) consisted of young children aged between 36 and 50 months old (Mean age = 44 months) Children were recruited from nursery schools located in a mid-sized town in a semi-rural county in the East of England. All children spoke English as their first language. No children were reported to have any learning or educational problems.

Design

A within-participants design was used. Stimulus Type (Manual, Word and Syllable) was the independent variable. Participant accuracy was the dependent variable.

Materials

Manual or Verbal responses and test sessions were audio-recorded using the same equipment used in Experiment 1 and 2a.

Procedure

SRC tasks used the same *if-A-then-B/if-B-then-A* rule structure and similar stimuli and responses as Experiment 1 and 2a (see Table 2.3). Each task comprised four practice trials (order ABAB) and 20 test trials in a pseudorandom order (ABBABAABBABAABABABBA). Imitation tasks were counterbalanced within each group which produced six orders overall. Task order was randomly allocated to each child. Children played two games in each of two testing sessions of approximately 10 minutes in duration across two days. Sessions were spaced not more than 10 days apart.

Before the tasks began the experimenter demonstrated the manual and verbal gestures, and children were asked to show that they too could do so. Children who were unable to show or say the correct gesture were corrected on their pronunciation or physical gesture. Once the child had successfully demonstrated the required verbal or manual gesture the experimenter and child practiced saying the word aloud or physically making the fist and finger pointing gesture.

The rules of the game were the same as Experiments 1 and 2a and were explained to the child by the experimenter. When the child had confirmed they understood the rules, four practice trials began. During practice trials participants were provided with feedback; the experimenter corrected incorrect responses and confirmed correct responses. Children who failed to get more than three practice trials correct repeated the four practice trials; however, before completing the second set of practice trials the experimenter reiterated the rules of the game to the child. Upon successful completion of three of four practice trials children were then invited to play the game 'for real' and told that they would receive a sticker at the

end of the game. Children who did not successfully pass three of four practice trials were omitted from involvement in the test session.

Prior to playing the game 'for real' the experimenter informed the child one final time of the game rules. The test trials then began. During test trials no feedback was provided for incorrect responses, however, the experimenter for all responses gave a confirmatory response of 'good' or 'well done'. Upon completion of the 20 test trials children were told that they had played a great game and were invited to pick a sticker of their choosing to keep. At the end of the first task children were thanked by the experimenter for taking part and asked if they would like to play another silly game. Upon completion of the second task the nursery school employee then returned the child to the main playroom.

2.4.3. Results

Total correct responses were summed for each SRC task and converted to form a percentage score (see Fig 2.9). Overall, accuracy in each of the three imitation tasks was relatively high – again suggesting that children were successfully learning the task rule. However, participant accuracy on each of the tasks was dissimilar. Children were more accurate on the Word condition than on the Manual and Syllable conditions.

First analysis of SRC data investigated differences between SRC tasks. A repeated measures ANOVA confirmed there was a statistically significant difference between the tasks F(2,52)=5.46,p=.007; and a small effect size (η_P^2=.17). Paired sample t-test comparisons showed statistically significant differences between Manual and Word conditions t(26)= -3.19, p=.004, 95% CI (5% - 23%). Using the Cohen's d effect size convention (Cohen, 1988),

the effect size for this analysis was found to be medium-large (0.61). ; and Syllable and Word conditions t(26)= -2.71, p=.012, 95% CI (2% - 17%). Using the Cohen's d effect size convention, the effect size for this analysis was found to be medium (0.52). Performance on the Syllable and Manual conditions did not differ t(26)= .87, p=.393.

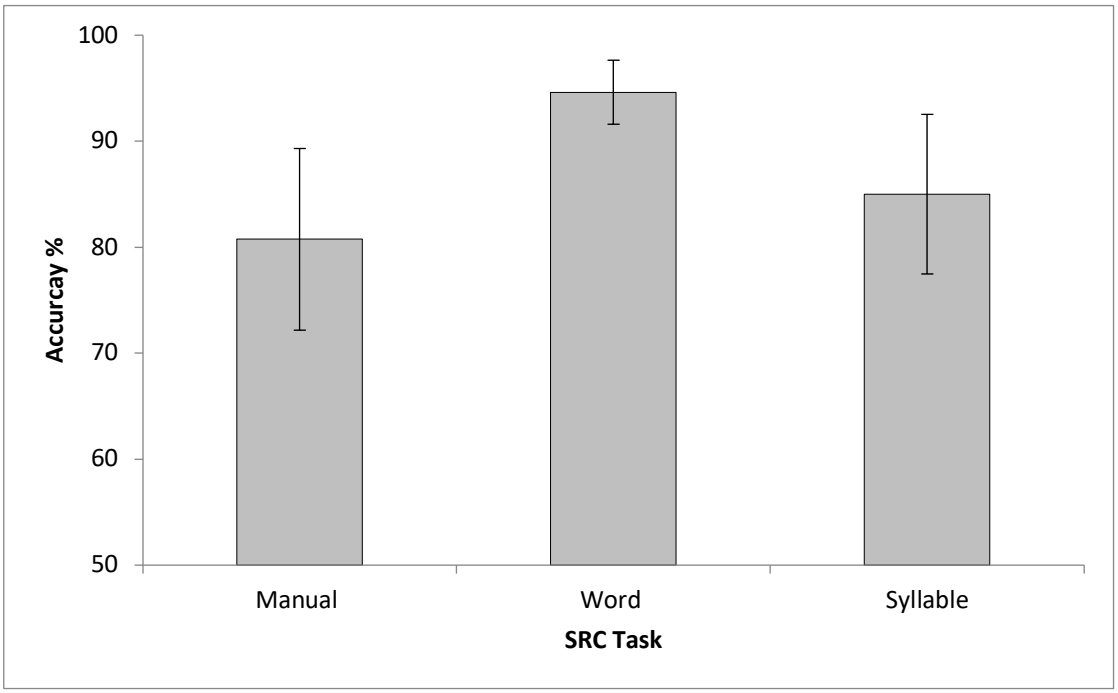


Figure 2.9. Percentage accuracy of three SRC tasks including SEM error bars in Experiment 2b.

Further analysis of SRC data investigated effects of gender (see Fig 2.10). The data were analysed using a mixed ANOVA with SRC task (Manual, Word, Syllable) as the within-participants factor and Gender (Male, Female) as the between participants factor. There was a significant main effect of SRC task F(2, 50) = 4.90,p=.011, however, the effect size was small η_P^2=.16. There was no significant main effect of gender F(1,25)=.28,p=.599, η_P^2=.01.

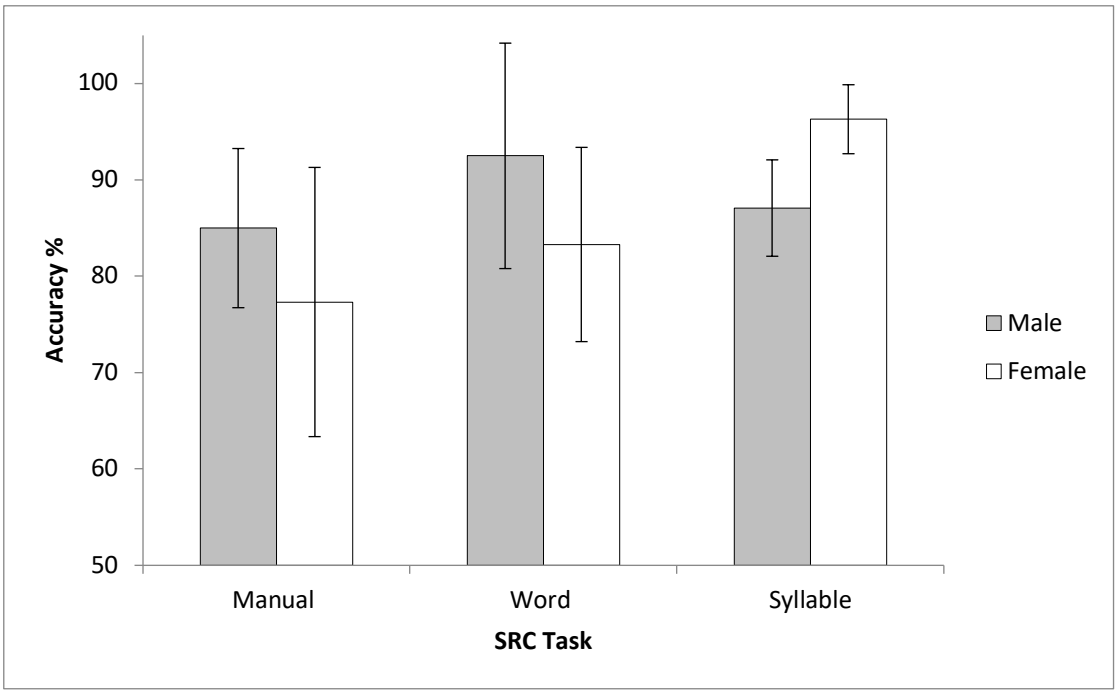


Figure 2.10. Male and Female accuracy on three SRC tasks including SEM error bars in Experiment 2b.

Further analysis of SRC data investigated effect of imitation SRC task order on accuracy (see Fig 2.11). I coded each condition based on its order of presentation 1 = MWS, 2 = MSW, 3 = WMS, 4 =WSM, 5 = SMW, 6 = SWM. A one way repeated measures ANOVA showed a significant main effect of SRC task F(2,42)=6.06,p=.005, indicating there was a difference between SRC tasks, however, there was a small effect size (η_P^2=.22). There was no main effect of SRC task order F(5,21)=1.536,p=.221, η_P^2=.268 indicating no difference between the order in which SRC tasks are completed and children's performance on SRC tasks.

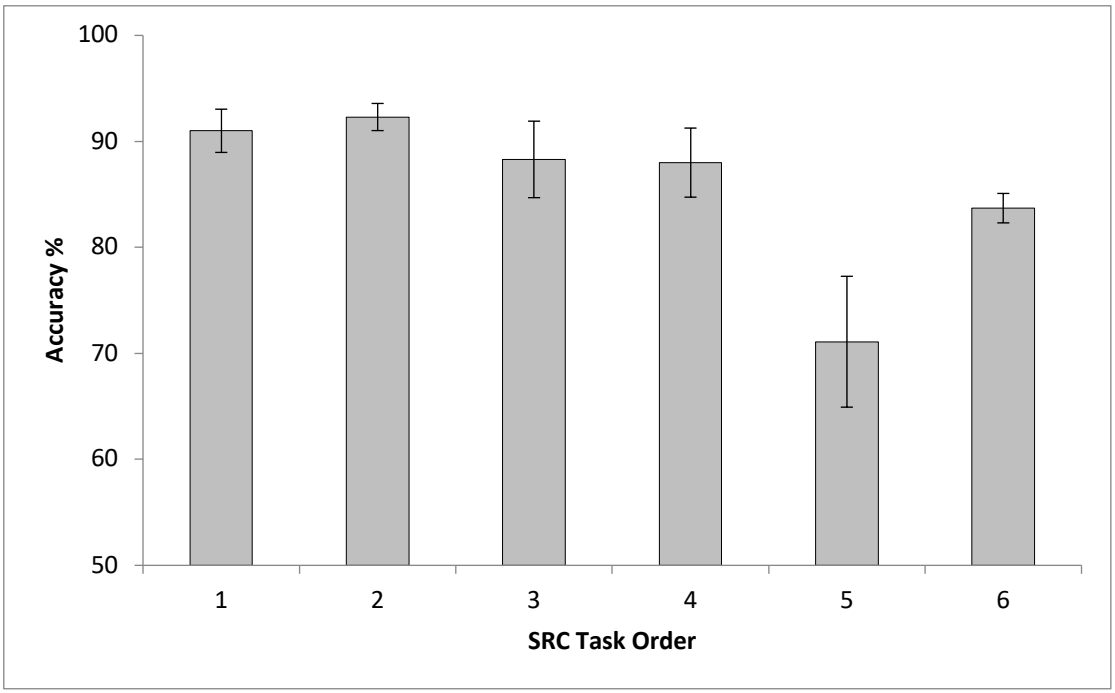


Figure 2.11. Percentage accuracy of three SRC tasks per SRC task order including SEM error bars in Experiment 2b.

I next investigated SRC task performance across trials. The twenty test trials were grouped to form blocks. Trials 1-4, 5-8, 9-12, 13-16, 17-20 were recoded into Blocks 1,2,3,4 and 5. Total scores were calculated per block for each imitation SRC task and converted to form a percentage score (see Fig 2.12). Performance within blocks for each imitation SRC task was not similar. Word imitation accuracy was best across each block. Syllable imitation was better than Manual imitation. Manual and Syllable imitation task accuracy was greatest in Block One and declined in Block Two. Word imitation accuracy was greatest in Block Two and declined during Blocks Two to Five.

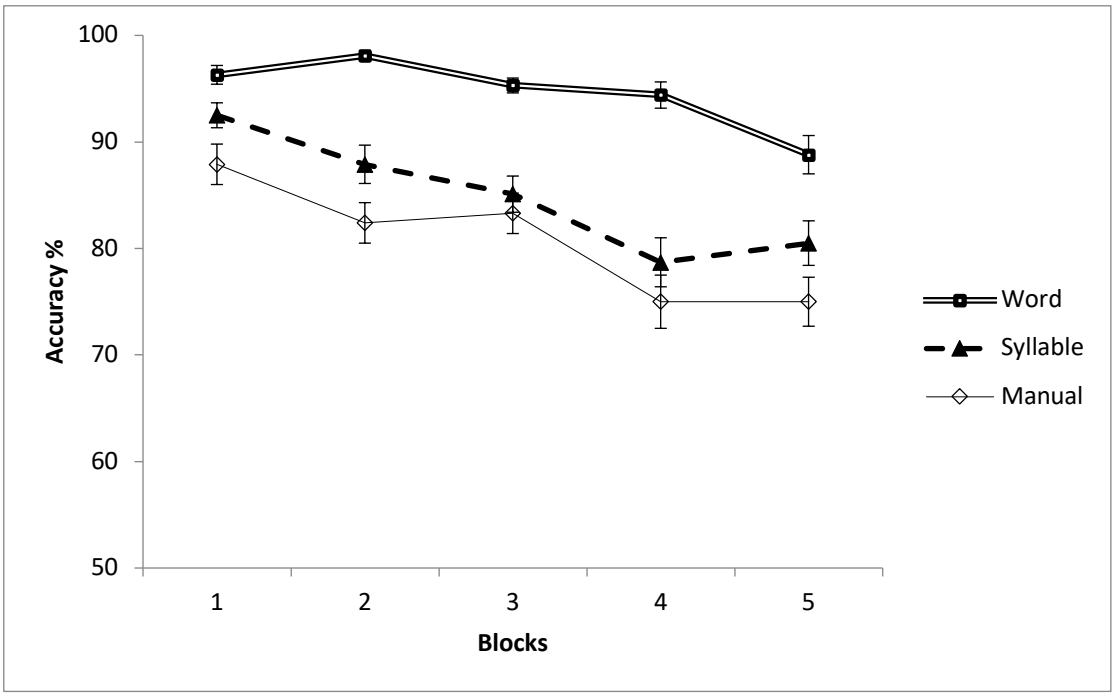


Figure 2.12. SRC imitation task performance across blocks including SEM error bars in Experiment 2b.

2.4.4. Discussion

The data from Experiment 2b were consistent with my hypothesis that verbal imitation is only easier than manual imitation when the verbal stimuli are more complex than the manual stimuli. Consistent with this Complexity account of resisting verbal imitation, performance on the Word condition was more accurate than on the Syllable condition. Under a Complexity account words are easier to resist imitating than syllables because words are complex. Word complexity creates a slow mapping between speech perception and production representations, and so reduced the need for IC. As a consequence, word complexity contributes to the ease with which children can resist verbal imitation.

2.5 General Discussion

The three experiments reported in this chapter explored the automaticity of verbal and manual imitation in SRC tasks. In Experiment 1, I used three Verbal imitation tasks (Word, Syllable and Vowel) and one Manual imitation task (Hand Game). Based on the Complexity account, I hypothesised that verbal imitation is only easier than manual imitation when the verbal stimuli are more complex. I predicted the Syllable and Vowel conditions (simple verbal stimuli) would be as difficult as the Manual condition. The result of Experiment 1 did not support my hypothesis: verbal imitation was not easier to resist than manual imitation on any of the three verbal conditions. Children's accuracy was low on all four SRC tasks. Thus, the results of Experiment 1 were not consistent with a Complexity account of verbal imitation: Words were not easier to resist than Syllables or Vowels. Nor did they replicate previous findings showing that Word imitation is easier for children to resist than Manual imitation (Simpson et al., 2013; Simpson & Carroll, 2014).

In Experiment 2a I continued my investigation of children's ability to resist manual and verbal imitation. Experiment 1 had showed children performed poorly across all SRC tasks. Poor performance might have been explained by children's inability to learn the task rules – particularly in the Verbal conditions (Simpson et al., 2013). In Experiment 2a I addressed concerns that this methodological weakness had impacted children's accuracy in Experiment 1. In Experiment 2a I scaffolded children's production of the verbal and manual responses. I also used a mixed design in order to reduce the number of arbitrary word pairs that each child had to learn. Experiment 2a used two Verbal imitation tasks (Word and Syllable) and one Manual imitation task (Hand game). Following the Complexity account, I again hypothesised

that verbal imitation is only easier than manual imitation when the verbal stimuli are more complex. The results of Experiment 2a did replicate previous findings (Simpson et al., 2013; Simpson & Carroll, 2014): Word imitation was easier to resist than Manual imitation. However, Experiment 2a results did not support a Complexity account: children were as accurate on the Syllable condition as the Word condition, and both Verbal conditions were easier than the Manual condition.

In Experiment 2b I continued my investigation of verbal and manual imitation in SRC tasks. One explanation for the similarity in accuracy between Word and Syllable conditions in Experiment 2a was that the inhibitory demands of the SRC tasks were too low to distinguish them. I therefore increased the number of test trials from 12 to 20 in an effort to increase the tasks' inhibitory demands. I also returned to a within-participants design, as this increased statistical power. To address continuing concern about children's ability to learn the task rules, a mandatory pre-test assessment was included. Children were required to answer at least three out of four practice trials correctly. In Experiment 2b I used two Verbal imitation (Word, Syllable) and one Manual imitation (Hand Game) tasks. The hypotheses and predictions were the same as in Experiment 2a. The results of Experiment 2b were consistent with previous findings: verbal imitation was easier to resist than manual imitation (Experiment 2a; Simpson et al., 2013; Simpson & Carroll, 2014). Furthermore, Experiment 2b results were consistent with the Complexity account: children were better able to resist Word imitation than Syllable imitation.

Taken together, the results of Experiments 1, 2a and 2b reported in this chapter show word imitation is less automatic than manual imitation: verbal imitation is easy to resist. The results

also provided some support for the Complexity account of why verbal imitation is not automatic with words. Under the Complexity account word imitation is easier to resist than syllable imitation. Word complexity makes imitating words easier to resist due to 'slow mapping' between speech perception and production representations. Words are more complex than are syllables. Motor representation of simple syllables is subject to greater activation of corresponding representations than complex whole words. In contrast, motor representations required for imitating whole words are activated very little, if at all. Resisting verbal imitation of words is therefore easy.

A Complexity account also explains the difference between child and adult verbal imitation data. Children find verbal imitation easy to resist (e.g. Simpson et al., 2013; Simpson & Carroll, 2014), whereas for adults verbal imitation is difficult to resist (e.g. Fowler et al., 2003). Importantly, however, stimuli and responses used in child and adult's verbal imitation studies are different: children use whole words (e.g. dog / cup) and adults use simple syllables (e.g. pa / ta). Under the Complexity account verbal imitation is less automatic with words. Thus, the difference between children's and adult's performance on SRC tasks is a function of the stimuli and responses used in the respective tasks: simple syllables are difficult to resist for adults, complex words are easy to resist for children.

However, while conducting the research presented in this chapter, it became clear that another account may explain why word imitation is less automatic. It may be that word imitation is easy to resist when stimuli and responses are different, that is, when they are dissimilar. A Dissimilarity account may also explain the results of the experiments in Chapter 2. In Experiments 1, 2a and 2b the Verbal stimuli and response pairs differed in terms of their

dissimilarity: in each of the three experiments Words did not rhyme (e.g. dog / cup), but Syllables did (e.g. woo / boo). The phonological dissimilarity between the stimuli and response pairs may therefore have contributed to greater accuracy on the Word conditions than on the Syllable conditions. Words were easier to resist than syllables because the Word stimuli and responses did not rhyme.

That dissimilarity was a confounding factor in Experiments 1, 2a and 2b suggests it was not possible to conclusively assert that word complexity accounts for children's ease with resisting word imitation. However, the results of Experiments 1, 2a and 2b did provide an interesting avenue for further exploration. Specifically, the ease with which children resist verbal imitation may be due to phonological dissimilarity rather than complexity: it is easier to resist verbal imitation when the stimulus and response are different. It was this hypothesis that I explored in the next chapter.

Chapter 3

Does the complexity or dissimilarity of stimuli and responses make verbal imitation easy for children to resist?

3.1. Introduction

In Chapter 2 I investigated verbal imitation and manual imitation in three experiments. In Experiment 1 I hypothesised that verbal imitation is only easier than manual imitation when the verbal stimuli are more complex. I predicted the Syllable and Vowel conditions would be as difficult as the Manual condition. The results did not support my hypothesis: accuracy was poor on all four tasks. In Experiment 2a I hypothesised that verbal imitation is only easier than manual imitation when the stimulus is more complex. However, the results were not consistent with a Complexity account: there was no difference between performance on the Word and Syllable conditions. In Experiment 2b I modified the SRC tasks to increase their inhibitory demands and reduce their working memory demands. I again hypothesised that verbal imitation is only easier than manual imitation when the stimulus is more complex. The results of Experiment 2b supported the Complexity account: Word imitation was easier to resist than Syllable imitation.

3.1.1. Does Complexity or Dissimilarity make verbal imitation easy to resist?

In this section I first discuss why verbal imitation is easy to resist according to the Complexity account of verbal imitation. I then propose the Dissimilarity account of verbal imitation. I then discuss how the Dissimilarity account can explain the results of Experiment 2b from Chapter 2 and other verbal imitation studies (e.g., Simpson et al., 2013).

The Complexity account of verbal imitation (Simpson et al. 2013; Simpson and Carroll, 2014) suggests the complex sequence of phonemes within words ultimately impacts on automaticity, and makes verbal imitation easy to resist. Phonemes are the basic vocal

gestures of language. For example, the word ‘dog’ has three phonemes (/d/o/g/), ‘bring’ has four phonemes (/b/r/i/ng/), ‘asked’ has four phonemes (/a/s/k/t/) and ‘strict’ has six phonemes (/s/t/r/i/c/t/). Arguably phonemes don’t really exist, however: the segmentation of words into phonemes is simply an abstraction of how a word is mentally represented. It is the complex nature of words – their phonemic composition - that creates a ‘slow mapping’ between speech perception and production representations. Speech motor representations are not activated, or are activated very little, when perceiving speech. Thus, word imitation is not automatic – and verbal imitation is easy to resist – because word complexity impedes the mapping from perceptual representations to motor representations.

The Complexity account provides a parsimonious explanation for the results of Experiment 2b in Chapter 2. Word imitation *was* easier to resist than syllable imitation due to Words being more complex than Syllables. Thus, imitation of words is not automatic. However, closer inspection of stimuli and responses used in Experiment 2b (Chapter 2) showed the words used did not rhyme (e.g., dog / cup), whereas the syllables did (e.g. woo / boo). In this respect, stimuli and response words were more dissimilar to each other (hear ‘dog’ say ‘cup’) than were syllables to each other (hear ‘woo’ say ‘boo’). It is possible stimuli and response dissimilarity improved performance on the Word imitation task compared to the Syllable imitation task, by making imitation less automatic in the Word task, and so reducing its inhibitory demands. This suggests an alternative explanation for the accuracy observed in the Word task: when stimuli and responses are dissimilar, verbal imitation is less automatic. Improved accuracy was a result of words (e.g. hear ‘dog’ say ‘cup’) being more dissimilar than syllables (e.g. hear ‘woo’ say ‘boo’). As a consequence, accuracy was better when the stimuli and responses were dissimilar i.e. when they did not rhyme.

The Dissimilarity account suggests that when stimuli and responses are dissimilar, verbal imitation is easy to resist. Rhyme is a particular kind of similarity – monosyllabic words have an onset and rhyme – and both kinds of similarity could be important. Take, for example, the words 'drum' and 'plate'. Perceiving the word 'drum' triggers a mental representation and corresponding motor program required for production of that word. In short, the word 'drum' becomes automatically activated. However, it is easy to resist verbal imitation of the word 'drum', when being required to produce the word "plate," as the words 'drum' and 'plate' are not similar in their onset or rhyme. Activation of the mental representation of the word 'drum' does not interfere with production of the motor program for the phonetically unrelated word 'plate', and little or no inhibition is required. In contrast, when words are similar, verbal imitation is automatic and is difficult to resist. For example, perceiving the word "crab" but being required to produce the word "grab" is potentially problematic, because the similarity of speech representations and motor programs activated upon perception of the word "crab" interfere with production of the phonetically related word 'grab'. Producing the word "grab" requires that the 'nearby' word crab is inhibited.

The Dissimilarity account is also compatible with children's verbal imitation performance on other verbal and manual imitation studies (e.g. Simpson et al., 2013). Simpson and colleagues showed imitation on a novel Word task (e.g., hear 'sun' say 'moon', hear 'moon' say 'sun') was easier to resist than was imitation on a Manual action task (e.g., see |finger| make a fist, see |fist| point a finger) - a finding which suggested that verbal imitation was less automatic than manual imitation. Simpson et al. (2013) construed word complexity led to better accuracy. However, the Dissimilarity account also explains better performance on the Word task over the Manual task. Words were dissimilar (e.g., 'sun' and 'moon') but manual actions

were not (e.g., |fist| and |finger|). Indeed, manual action stimuli and responses were actually very similar: both hand actions required the four digits to be held tightly into the palm of the hand, and only the extension of the forefinger, in the finger response, differed slightly from the fist gesture. As a result of the similarity between the manual gestures, resisting manual imitation might have been more difficult than resisting verbal imitation. Thus, the Dissimilarity account could explain why children were better able to resist word imitation than manual imitation in Simpson et al. (2013).

The Dissimilarity account also 'makes sense' of child and adult verbal imitation studies. Simpson et al. (2013), for example, found verbal imitation was easier to resist than manual imitation: verbal imitation *is not* automatic in young children. In contrast, Mottonen & colleagues (2013) found that Transcranial Magnetic Stimulation disruption of the articulatory motor cortex impaired perception of simple speech sounds. Data that indicated hearing speech automatically activated motor representations of that speech, and that – for adults – verbal imitation *is* automatic. However, adult (e.g. Mottonen et al., 2013; Fowler et al., 2006) and child (Simpson et al., 2013; Simpson and Carroll, 2014) studies used different stimuli and responses: child studies use words, whereas adult studies use syllables. Importantly, the words were dissimilar – they did not rhyme (e.g., 'dog' and 'cup'); but the syllables were similar – they did rhyme (e.g., 'pa' and 'ta'). The Dissimilarity account suggests the observed disparity in verbal imitation automaticity between children and adults is due to differences in the similarity of stimuli and responses used when studying them.

3.1.2. The studies in this chapter

The three experiments (3, 4 and 5) reported in Chapter 3 built on research that shows word imitation is not automatic (e.g. Chapter 2, this thesis; Simpson et al., 2013; Simpson & Carroll, 2014). Developing the findings of Chapter 2 I explored in Chapter 3 whether it is the complexity or dissimilarity of stimuli and responses that makes word imitation easy to resist. The Complexity account suggests it is easy to resist word imitation when stimuli and responses are complex (i.e. when they are multiple phoneme words). Speech representations are not activated, or are activated only very little, due to slow mapping between speech perception and production representations. The Dissimilarity account of verbal imitation suggests it is easy to resist word imitation when stimuli and responses are phonetically different (i.e. they don't rhyme). Automatically activated speech representations of words do not interfere with speech production representations when words are not phonetically alike.

Experiment 3 employed a factorial design (Dissimilarity x Complexity) to investigate the need for IC when resisting verbal imitation. Preschoolers were tested on four Word imitation tasks; Dissimilar-Complex (e.g., hear 'hand' say 'water', hear 'water' say 'hand'), Dissimilar-Simple (e.g., hear 'shoe' say 'bee, hear 'bee' say 'shoe') and two Similar-Complex conditions (e.g., hear 'clown' say 'cloud', hear 'cloud' say 'clown' and hear 'sound' say 'round', hear 'round' say 'sound'). Under the Word Complexity hypothesis, it is harder to resist imitating Simple words than Complex words. It predicts Complex conditions will be easier than Simple conditions. Under the Word Dissimilarity hypothesis, it is harder to resist imitating when the stimulus and response are phonetically similar than when they are dissimilar. It predicts Similar conditions would be harder than the Dissimilar conditions. The results of Experiment

3 supported the Dissimilarity account: *accuracy* was best when stimuli and responses were dissimilar rather than when they were similar, regardless of complexity.

Experiment 3 investigated verbal imitation with preschoolers. However, 3-year-olds have problems with learning Verbal task rules. If children can't learn the rules correctly then IC is not being tested. To be confident that children knew the task rules – and therefore, that IC was being tested – in Experiment 4 I tested children aged 5- and 7-years-old. Children of this age have better IC (see Peterson et al., 2016) than younger children – though not as good as adults – and so a more sensitive measure of performance was included. In Experiment 4 I tested reaction time as well as accuracy.

Experiment 4 also employed a factorial design (Dissimilarity x Complexity) to investigate the need for IC when resisting in verbal imitation. I used four Word imitation conditions: Simple-Similar (e.g. hear 'Bee', say 'Key'), Complex-similar (e.g. hear 'Crab', say 'Grab'), Simple-Dissimilar (e.g. hear 'Egg', say 'Day') and Complex-Dissimilar (e.g. hear 'Bread', say 'Milk'). Under the Complexity hypothesis, it is harder to resist imitating Simple words than Complex words. It predicts Complex conditions will be easier than Simple conditions. Under the Dissimilarity hypothesis, it is harder to resist imitating when the stimulus and response are similar than when they are dissimilar. It predicts Similar conditions would be harder than the Dissimilar conditions. The results for Experiment 4 showed similarity determined the difficulty with resisting verbal imitation (with both accuracy and reaction time measures), and were *broadly* consistent with the Dissimilarity account. However, Experiment 4 showed a Similarity and Complexity interaction: reaction time on the Similar-Complex task was lower than on the Similar-Simple task. This may have been due to a confound: the Similar-Complex task used

words with three of four phonemes the same (75% similar), whereas the Similar-Simple condition used words with one of two phonemes the same (50% similar). In this respect, Similar-Complex words were actually more phonetically similar than Similar-Simple words.

Experiment 5 tested 5- and 7-year-olds on four Word imitation tasks. Word pairs which varied on their similarity: zero phonemes (e.g., Sink/Crawl), one phoneme (e.g., Snack/Clock), two phonemes (e.g., Stick/Click) and three phonemes (e.g., Slap/Clap). Under the Word Dissimilarity hypothesis, it is harder to resist imitating when the stimulus and response are similar than when they are dissimilar. It predicts the accuracy on word conditions would be harder the more similar the stimuli and responses were (on both accuracy and reaction time measures). The results of Experiment 5 supported the Dissimilarity account: word conditions were harder the more similar the stimuli and responses.

3.2. Experiment 3

3.2.1 Introduction

In Experiments 2a and 2b I obtained evidence that verbal imitation is easier for young children to resist than manual imitation. Experiment 2b suggested that verbal imitation is not always easier to resist than manual imitation, as resisting syllable imitation was as difficult as resisting manual imitation. A Complexity account of word imitation accounts for this finding: word imitation is not automatic because words are complex. Word complexity creates a 'slow' mapping' between speech perception and production representations. As a result, children need little IC when resisting word imitation. However, I noticed that there was a difference

between the words and syllables used in the Experiments in Chapter 2 other than their complexity: this difference was in their phonetic similarity. The Word pairs used in SRC tasks did not rhyme (e.g. dog / cup), but Syllable pairs did (e.g. woo / boo). It is possible that this difference between words and syllables accounted for the results of Experiment 2b. Dissimilarity may have caused the Word task to have lower inhibitory demands than the Syllable task.

Experiment 3 compared the Complexity and Dissimilarity accounts of resisting verbal imitation. I used three Verbal imitation tasks: Dissimilar-Complex, Dissimilar-Simple and Similar-Complex (Table 3.1). Under the Word Complexity hypothesis, it is harder to resist imitating Simple words than Complex words. It predicts Complex conditions will be easier than Simple conditions. Under the Word Dissimilarity hypothesis, it is harder to resist imitating when the stimulus and response are similar than when they are dissimilar. It predicts Similar conditions would be harder than the Dissimilar conditions. Experiment 3 investigated two different types of word complexity – complex and simple and two different types of similarity: similar words had three identical phonemes and either differed at just their first phoneme (*S/*ou/n/d/ and *R/*ou/n/d/) or at just their last phoneme (C/l/ow/*n*/ and C/l/ou/d/).

Table 3.1. The three Word imitation SRC conditions used in Experiment 3.

Word imitation SRC Task	Word Imitation Conditions
Dissimilar-Complex	Hear ‘hand’ say ‘water’, hear ‘water’ say ‘hand’.
Dissimilar-Simple	Hear ‘shoe’ say ‘bee, hear ‘bee’ say ‘shoe’
Similar-Complex	Hear ‘clown’ say ‘cloud’, hear ‘cloud’ say ‘clown’. or Hear ‘sound’ say ‘round’, hear ‘round’ say ‘sound’

3.2.2 Methods

Participants

Study participants (N=57) consisted of young children aged between 38 months and 49 months (Mean age = 43 months); 16 female. Children were recruited from nursery schools located in a mid-sized town in a semi-rural county in the East of England. All children spoke English as their first language. No children displayed any learning or educational problems.

Design

A mixed design was used. Dissimilarity (Similar, Dissimilar) was the within-subjects factor and Complexity (Complex, Simple) was the between-subjects factor. The stimulus presented was the independent variable: Dissimilar-Complex (n=29), Dissimilar-Simple (n=29) and Similar-Complex Clown / Cloud (n=15); Similar-Complex Sound / Round (n=29). Participant accuracy was the dependent variable.

Materials

A modified version of the researcher-devised chart used in Experiments 1, 2a and 2b logged participant responses. Test sessions were recorded using Audacity software and in-built microphone equipment on an Apple Macbook Pro laptop computer.

Procedure

SRC tasks used an *if-A-then-B/if-B-then-A* rule structure. Each SRC task comprised four practice trials (order ABAB) and 20 test trials in a pseudorandom order (ABBABAABBABA ABABABBA). Children took part in two sessions of approximately 10 minutes in duration.

Imitation task responses were counterbalanced within each group and produced six orders overall. Task response order was randomly allocated to each child.

Prior to beginning the tasks children were asked to show that they could make the verbal gesture required. Children who were unable to voice the response entirely or correctly were prompted and/or corrected on their pronunciation. Children who were unwilling or unable to make the correct verbal gesture were deemed unable to take part in the task and were not considered for further inclusion in the task practice and test sessions. Children who successfully voiced the required verbal gesture practiced doing so along with the experimenter.

The rules of the game were the same as Experiments 1, 2a and 2b. When the experimenter had received confirmation that the child understood the rules of the game, four practice trials began. During practice trials participants were provided with feedback; the experimenter corrected incorrect responses and confirmed correct responses. Children who failed to get at least three practice trials correct during the first set of four practice trials repeated the practice trial procedure. Children who did not successfully complete a second set of practice trials were omitted from further involvement in the test session. Upon successful completion of the practice trials children were invited to play the game 'for real' and told that they would receive a sticker at the end of the game. Prior to playing the game 'for real' the experimenter informed the child one final time of the game rules. The test trials then began.

During test trials, no feedback was provided for incorrect responses, however, a confirmatory response of 'good' or 'well done' was given by the experimenter for all responses. Upon completion of the twenty test trials children were told that they had played a great game and

were invited to pick a sticker of their choosing to keep. At the end of the first task children were thanked by the experimenter for taking part and asked if they would like to play another 'silly game'. Upon completion of the second task the nursery school employee then returned the child to the main playroom.

3.2.3 Results

Total correct responses were summed for each Word imitation task and converted to form a percentage score (see Fig 3.1). Differences observed in children's accuracy in the tasks was not the same. Performance was worse on the Similar condition (Clown /Cloud) than the Dissimilar condition (e.g. Shoe / Bee).

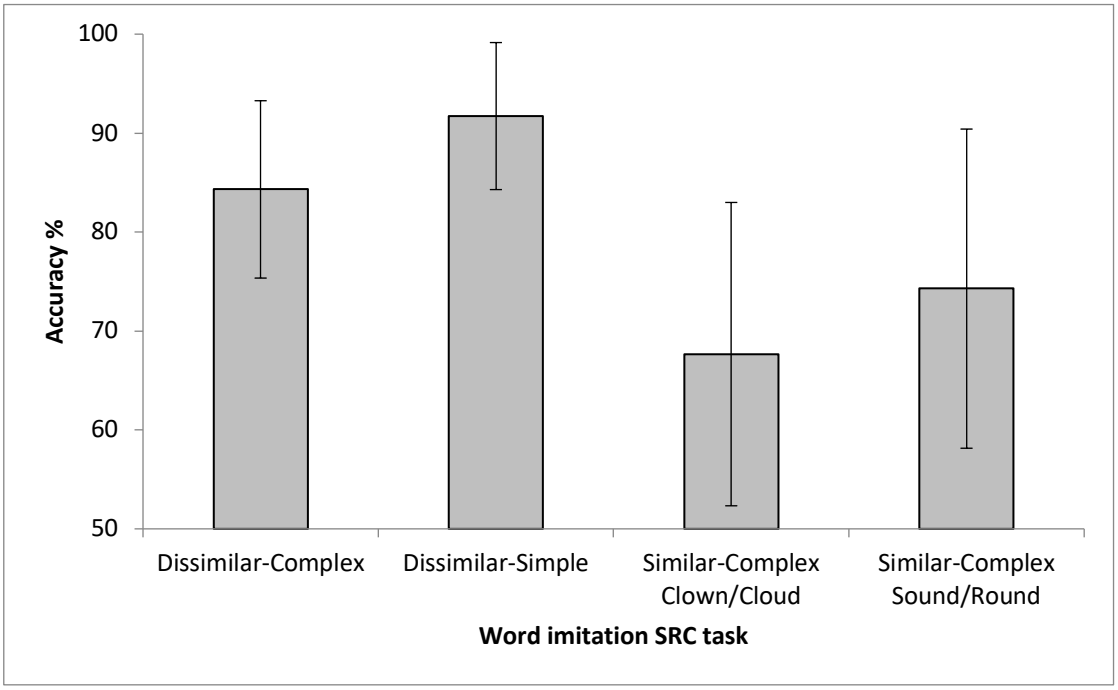


Figure 3.1. Percentage accuracy of four Word imitation SRC tasks including SEM error bars used in Experiment 3.

I first investigated for differences between word imitation tasks. A t-test showed the two Similar-Complex conditions (Clown/Cloud and Sound/Round) were not significantly different t(25)= -.46, p=.662. I then collapsed these two variables to form a single Similar-Complex variable.

Further analysis investigated differences between the three conditions (Dissimilar-Complex, Dissimilar-Simple and Similar-Complex). A one-way ANOVA showed F(2,86)=4.85,p<.05. indicating there was a statistically significantly difference between the group means. Next, a paired samples t-test compared the Dissimilar-Complex and the Similar-Complex conditions, and showed a significant difference between the two conditions t(28)=2.27, p<.05, 95% CI (1% - 26%). Using the Cohen's d effect size convention, the effect size for this analysis was found to be small-medium (0.42). A paired samples t-test also investigated differences between Dissimilar-Complex and Dissimilar-Simple and showed no significant difference between the two conditions t(28)= -1.69, p= .103.

Further analysis of SRC data investigated effects of gender (see Fig 3.2). The data were analysed using a mixed ANOVA with SRC task type (Dissimilar-Complex, Dissimilar-Simple and Similar-Complex) as the within-participants factor and Gender (Male, Female) as the between participants factor. Mauchly's test indicated assumptions of sphericity had been violated, $\chi^2(2)=9.25$,p<.001, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε =.77). There was a significant main effect for word type F(1.53,54)=7.94,p=.003, suggesting there was a difference between children's accuracy on the three Word imitation SRC tasks; however, the effect size was small (η_P^2=.23). There was no significant main effect of gender F(1,27)=.00,p=.998, η_P^2=.00.

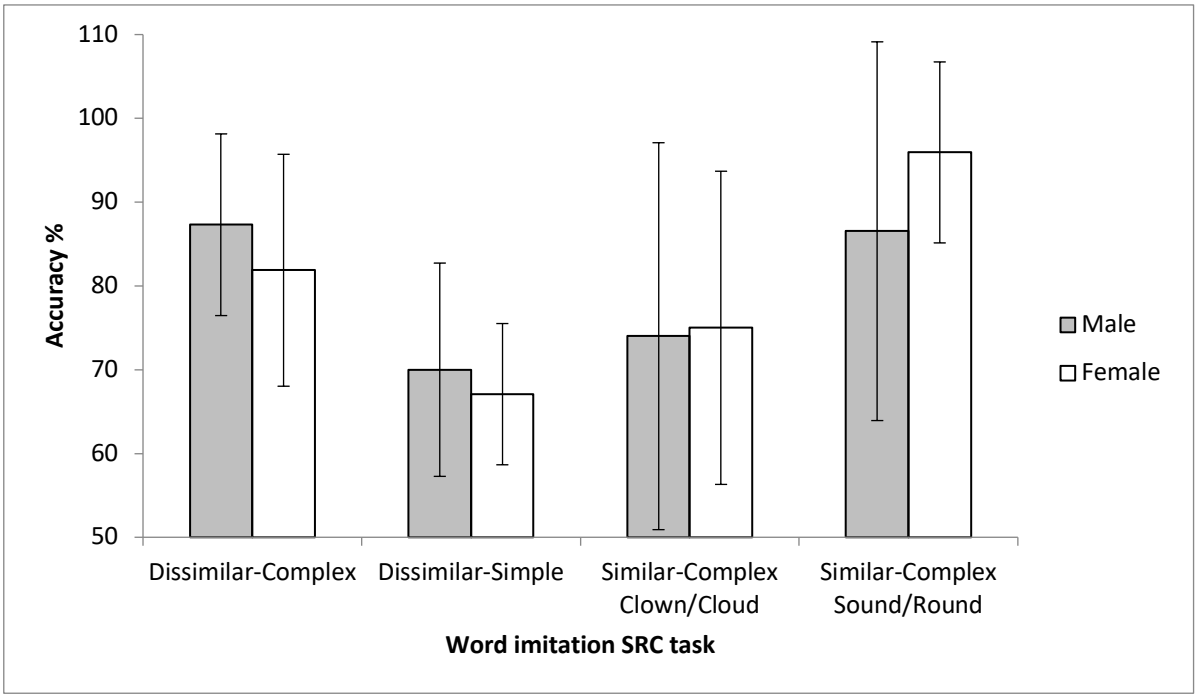


Figure 3.2. Male and Female accuracy on three Word imitation SRC tasks including SEM error bars in Experiment 3.

Next, I investigated the effect of task order (1=HW/CC/SB; 2=CC/SB/HW; 3=SB/HW/CC; 4=HW/SR/SB; 5=SR/SB/HW; 6=SB/HW/SR) on task accuracy (see Fig 3.3). A one way repeated measures ANOVA indicated a main effect of task $F(2,46)=7.96, p<.001$, however, there was a small effect size ($\eta_P^2=.26$). There was no main effect of SRC task order $F(5,23)=1.07, p=.401$, $\eta_P^2=.19$ indicating there is no difference between the order in which Word imitation tasks are completed and children's performance accuracy.

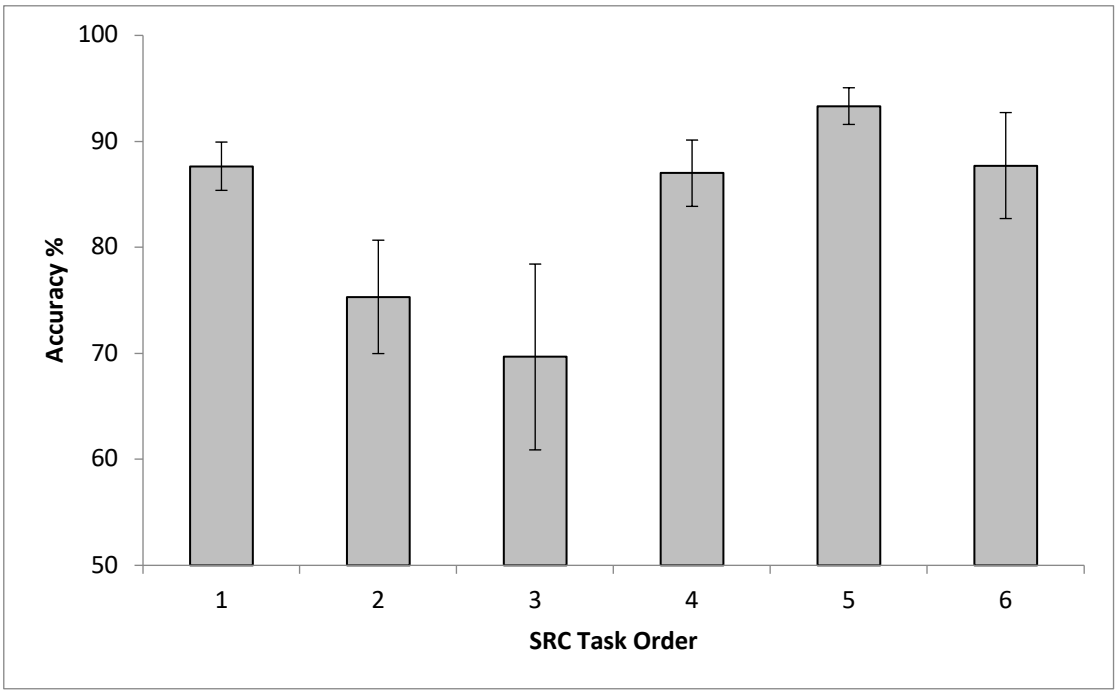


Figure 3.3. Percentage accuracy of three Word imitation SRC tasks per SRC task order in Experiment 3.

Finally, I investigated SRC task performance across trials. Previous research shows children's performance decreases across SRC task trials: accuracy is better on trials that appear earlier in the task than those that appear later. To investigate SRC trial performance across the whole task, the 20 trials in Experiment 3 were grouped to form quartiles (Trials 1-4, 5-8, 9-12, 13-16). It was expected that accuracy would deteriorate in later trials. The twenty test trials were grouped to form blocks. Trials 1-4, 5-8, 9-12, 13-16, 17-20 were recoded into Blocks 1,2,3,4 and 5. Total correct scores were calculated per block for each Word imitation SRC task and converted to form a percentage score (see Fig 3.4). Performance accuracy across each block was not similar for each SRC task. For all imitation task's accuracy was greatest in Block One. Dissimilar-Simple performance was sustained over blocks two and three before declining in blocks four and five. Dissimilar-Complex performance declined in blocks two and three before improving in block four and then block five. Similar-Complex (Clown/Cloud) performance

declined steadily over blocks one to five. Similar-Complex (Sound/Round) performance decreased in blocks two and three before increasing in block four and declining in block five. Overall, performance accuracy was greatest over all blocks in the Dissimilar-Simple task.

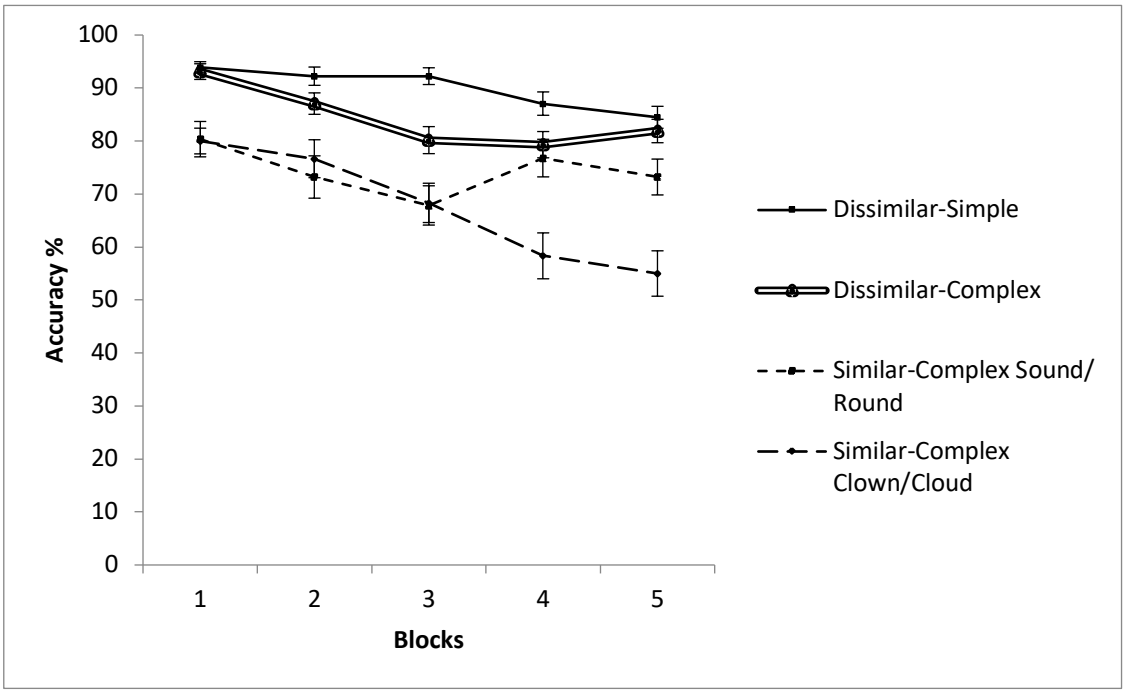


Figure 3.4. Word imitation SRC imitation task performance across blocks in Experiment 3.

3.2.4 Discussion

Experiment 3 investigated the need for IC when resisting in verbal imitation. It used three Word imitation SRC tasks: Dissimilar-Simple (Shoe/Bee), Dissimilar-Complex (Hand/Water), and Similar-Complex (Sound/Round or Clown/Cloud). Under the Word Complexity hypothesis, it is harder to resist imitating simple words than complex words. It predicts Complex conditions will be easier than Simple conditions. Under the Word Dissimilarity hypothesis, it is harder to resist imitating when the stimulus and response are similar than when they are dissimilar. It predicts Similar conditions would be harder than the Dissimilar conditions. The results of Experiment 3 showed accuracy was best on the Dissimilar condition

and worst on the Similar condition. The Sound/Round or Clown/Cloud conditions were not different – so it didn't seem to matter whether the words were dissimilar at the start or end of the word. Performance (in quartiles) across trials was commensurate with other research that shows decreasing accuracy. The results of Experiment 3 support the Dissimilarity account but not the Complexity account: verbal imitation is easier to resist when words are dissimilar, not when they are complex.

3.3. Experiment 4

3.3.1 Introduction

Experiment 3 investigated verbal imitation in SRC tasks. The results showed accuracy was best when stimuli and responses were dissimilar, and were consistent with the Dissimilarity account of resisting verbal imitation. Under the Dissimilarity account verbal imitation is easy to resist when words are phonetically dissimilar. It is possible, however, that the 3-year-olds in Experiment 3 had struggled to learn the rules, and this affected their performance. If they couldn't learn the rules, then IC was not being tested. To be confident that children did know the task rules in Experiment 4, I tested children aged 5- and 7-years-old. Because children of this age have better IC (see Peterson et al., 2016) than younger children, a more sensitive measure of performance was also used. In Experiment 4 I tested accuracy and reaction time. Five- to 7-year-olds were the youngest age group that I was confident would be able to remember the rules, based on evidence from previous research (Simpson et al., 2013).

Experiment 4 used four Word imitation tasks in a 2x2 factorial design: Dissimilar-Simple, Dissimilar-Complex, Similar-Simple and Similar-Complex. Table 3.2 shows the eight rule pairs

– as two different rule pairs were used for each condition. Dissimilar words were different in onset and rhyme; Similar words have different onsets (a single phoneme) but the same rhyme. Onsets are different so that both dissimilar and similar words can be distinguished equally quickly (i.e., Word pairs could always be distinguished by their first phoneme). This is important because reaction times were measured in this experiment. Additionally, Simple words contained two phonemes (e.g. e/gg/ or d/ay/) and Complex words contained four phonemes (e.g. b/r/i/ck and s/t/i/ck). Under the Word Complexity hypothesis, it is harder to resist imitating simple words than complex words. It predicts Complex conditions will be easier than Simple conditions. Under the Word Dissimilarity hypothesis, it is harder to resist imitating when the stimulus and response are similar than when they are dissimilar. It predicts Similar conditions would be harder than the Dissimilar conditions.

Table 3.2. The eight Word imitation SRC task word conditions used in Experiment 4.

Word SRC imitation task	Pair 1	Pair 2
Dissimilar-Simple	Hear ‘egg’ say ‘day’, hear ‘day’ say ‘egg’	Hear ‘tea’ say ‘boy’, hear ‘boy’ say ‘tea’
Dissimilar-Complex	Hear ‘bread’ say ‘milk’, hear ‘milk’ say ‘bread’	Hear ‘drum’ say ‘tent’, hear ‘tent’ say ‘drum’
Similar-Simple	Hear ‘bee’ say ‘key’, hear ‘key’ say ‘bee’	Hear ‘bye’ say ‘pie’, hear ‘pie’ say ‘bye’
Similar-Complex	Hear ‘crab’ say ‘grab’, hear ‘grab’ say ‘crab’	Hear ‘brick’ say ‘stick’, hear ‘stick’ say ‘brick’

3.3.2 Methods

Participants

Study participants (N = 48) consisted of 24 children aged 5-years-old: 12 female, and 24 children aged 7-years-old; 12 female. Children were recruited from two primary schools located in a mid-sized town in a semi-rural county in the East of England. All children spoke English as their first language. No children displayed any learning or educational problems.

Design

A repeated measures design was used. The independent variables were Complexity (Simple words versus Complex words) and Similarity (Similar versus Dissimilar words). Participant accuracy and reaction time were the dependent variables.

Materials

Verbal responses were recorded using the same audio program and equipment used in Experiment 3. Two stimulus response word pairs were created for each experimental condition. Simple and complex words comprised of a single syllable. Simple words contained two phonemes and complex words four phonemes. Similar word pairs contained two words with different onset but identical rhyme. Dissimilar word pairs contained two words that differed in all respects.

Procedure

SRC tasks used the same *if-A-then-B/if-B-then-A* rule structure as Experiment 3 (see Table 3.1). Each SRC task comprised four practice trials (order ABAB) and 16 test trials in a pseudorandom order (ABBABAABBABAABABABBA). Children took part in two sessions of

approximately five minutes in duration. SRC responses were counterbalanced within each group which produced 24 orders overall. SRC response order was randomly allocated to each child. Prior to beginning the SRC tasks children were asked to show that they could make the verbal gesture required. Children who were unable to voice the response entirely or correctly were prompted and/or corrected on their pronunciation. Children who were unwilling or unable to make the correct verbal gesture were deemed unable to take part in the SRC task and were not considered for further inclusion in the SRC task practice and test sessions. Children who successfully voiced the required verbal gesture practiced doing so along with the experimenter.

The rules of the game were verbally provided in the same manner as in Experiment 3. For example, the experimenter said to each child: 'When I say 'bee' (pointing to his mouth), then you say 'key' (pointing to the child's mouth), and when I say 'bye' (pointing to his mouth), you say 'pie' (pointing to the child's mouth). When the experimenter had received confirmation that the child understood the rules of the game, four practice trials began. During practice trials participants were provided with feedback; the experimenter corrected incorrect responses and confirmed correct responses. Children who failed to get at least three practice trials correct during the first set of four practice trials repeated the practice trial procedure. Children who did not successfully complete a second set of practice trials were omitted from further involvement in the test session. Upon successful completion of four practice trials children were invited to play the game 'for real' and told that they would receive a sticker at the end of the game. Prior to playing the game 'for real' the experimenter informed the child one final time of the game rules. The test trials then began.

During test trials no feedback was provided for incorrect responses, however, a confirmatory response of 'good' or 'well done' was given by the experimenter for all responses. Upon completion of the 16 test trials children were told that they had played the game well and were invited to pick a sticker of their choosing to keep. At the end of the first task children were thanked by the experimenter for taking part and asked if they would like to play another silly game. Upon completion of the second SRC task the nursery school employee then returned the child to the main playroom.

3.3.3 Results

Accuracy

Total correct accuracy scores were calculated for 5- and 7-year-olds for each Word imitation SRC task, summed, and converted to form a percentage (see Figure 3.5). Five-year-olds accuracy was greatest on the Dissimilar-Simple task and worst on Similar-Complex tasks. Seven-year-olds accuracy was greatest on both Dissimilar-Simple and Dissimilar-Complex tasks; performance was worst on the Similar-Complex task.

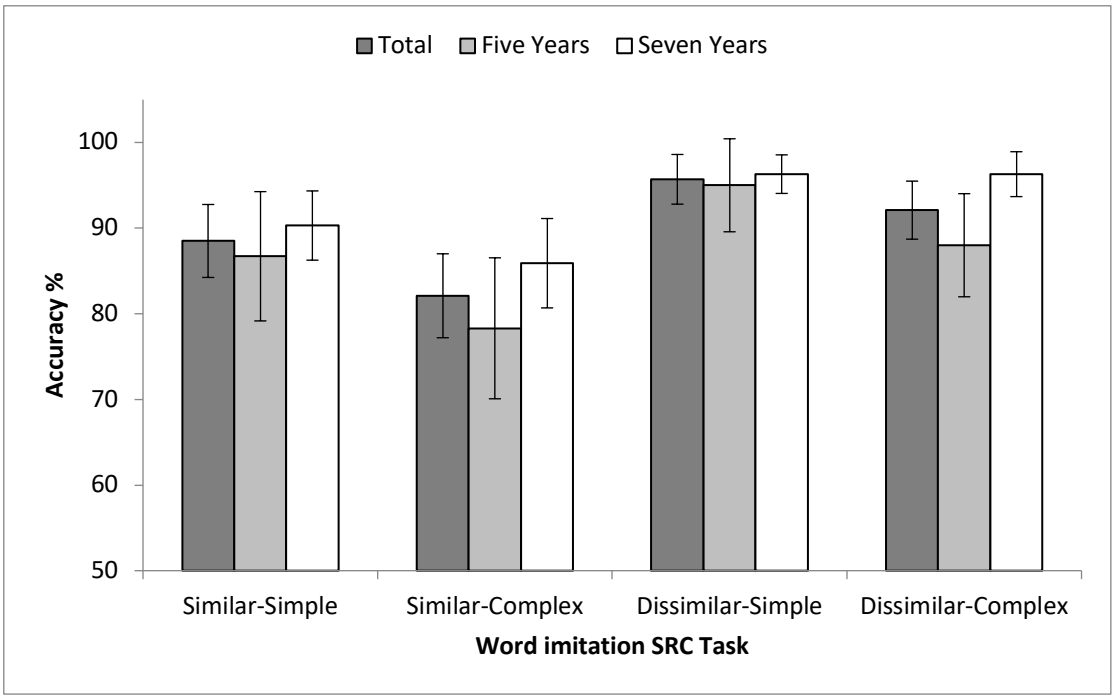


Figure 3.5. Percentage accuracy of four Word imitation SRC conditions including SEM error bars in Experiment 4.

A two-way repeated measures ANOVA was conducted that examined the effect of Complexity and Similarity on accuracy. There was a main effect of Complexity F(1,46)=9.09,p=.004, η_P^2 =.17. There was a main effect of Similarity F(1,46)=21.23, p<.001, however, there was a small-medium effect size (η_P^2=.32). There was no significant interaction between Complexity and Similarity F(1,46)=1.10, p=.299, η_P^2 =.02. Fig 3.6 shows word accuracy was better when words were Dissimilar rather than Similar, and when words were Simple rather than Complex.

A 2x2x2 ANOVA was carried out to examine the effect of Complexity, Similarity and Age on performance accuracy. There was no interaction between Complexity and Age F(1,46)=2.78, p=.102, η_P^2 =.06. There was no interaction between Similarity and Age F(1,46)=0.44, p=.835, η_P^2 =.00.

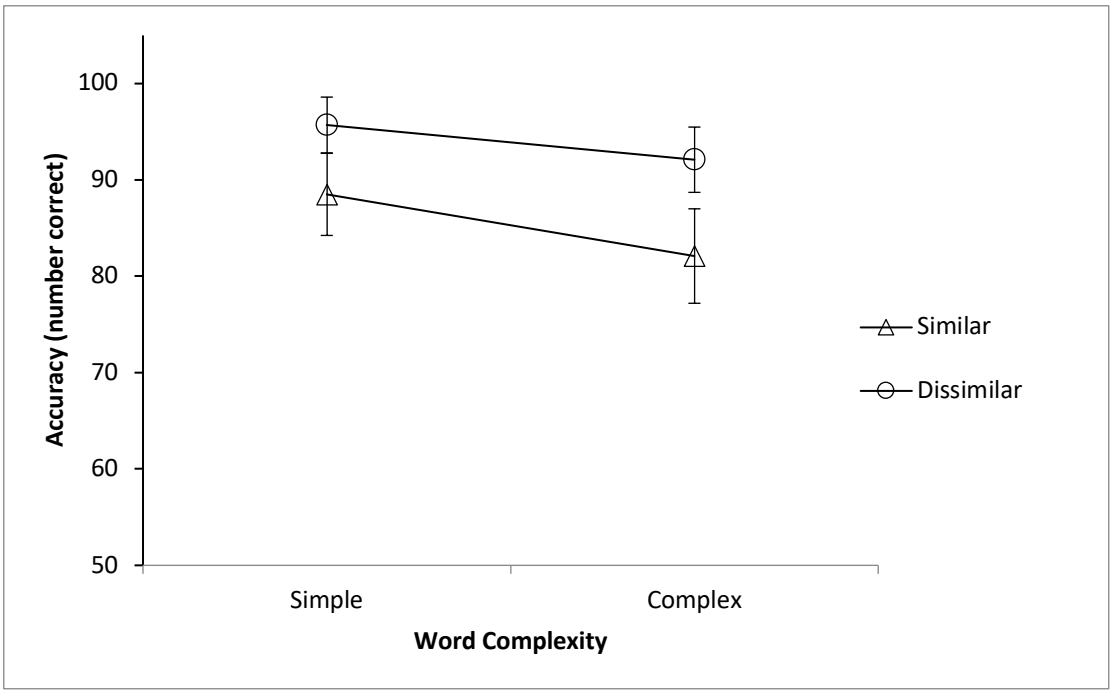


Figure 3.6. Participant accuracy on each of the four Word imitation SRC tasks including SEM error bars in Experiment 4.

Reaction Time

Reaction times were calculated for all 5- and 7-year-olds on each of the four SRC tasks. Reaction times were then added together for each of the SRC tasks and divided by the number of participants to create an average (see Fig 3.7). Five-year-olds reacted faster on the Dissimilar-Simple task. Seven-year-olds reacted fastest on Dissimilar-Simple and Dissimilar-Complex tasks. Five-year-olds and 7-year-olds were slowest on the Similar-Complex SRC task.

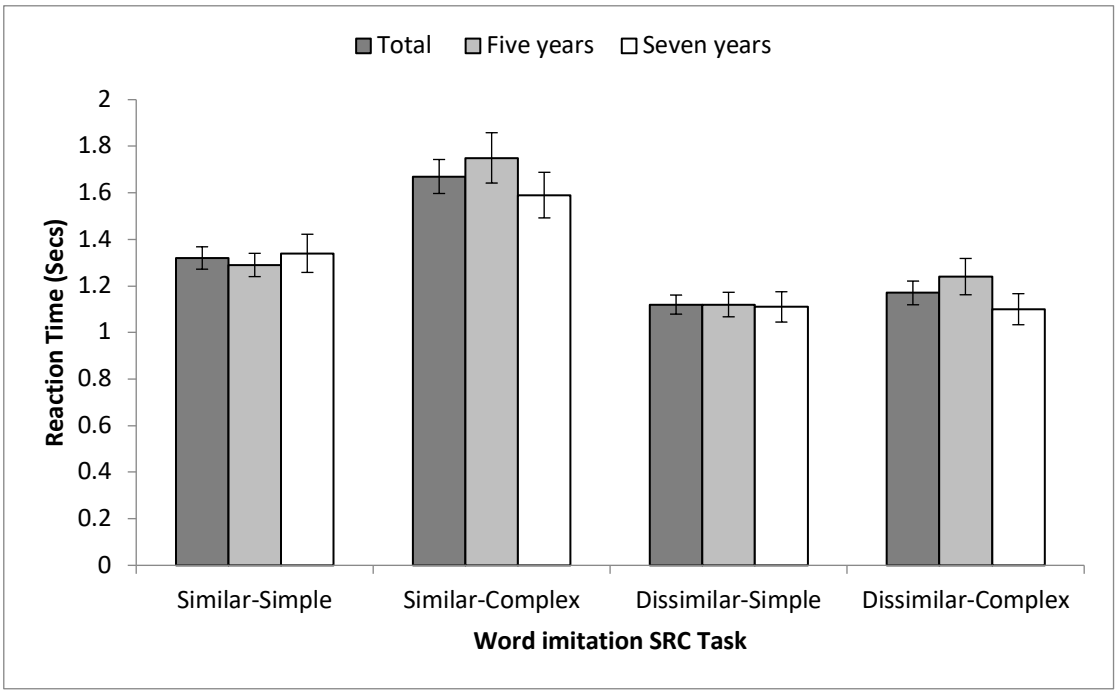


Figure 3.7. Reaction time of four Word imitation SRC tasks including SEM error bars in Experiment 4.

A two-way repeated measures ANOVA was conducted that examined the effect of Complexity and Similarity on reaction time. There was a main effect of Complexity F(1,46)=27.74, p<.001, and a medium effect size (η_P^2 =.38). There was a main effect of Similarity F(1,46)= 61.64,p<.001, and a medium effect size (η_P^2 =.57). There was an interaction between Complexity and Similarity F(1,46)= 10.38, p=.002, but with a small effect size (η_P^2 = .18). Fig 3.8 shows reaction time was faster when words were dissimilar rather than similar, and when words were simple rather than complex.

Follow-up tests of the interaction compared differences between reaction times using paired samples t-tests; they showed a statistically significant difference between children's responding in the Similar-Complex task than the Similar-Simple task t(47)=-4.76, p<.001, 95% CI (1% - 3%). Using the Cohen's d effect size convention, the effect size for this analysis was

found to be medium-large (0.68); responding was slower on the Similar-Complex task. However, although children responded slower in the Dissimilar-Complex task than the Dissimilar-Simple task, this difference was not statistically significant t(47)=-1.21, p=.233.

A 2x2x2 ANOVA was carried out to examine for effects of Complexity, Similarity and Age on Reaction Time. There was an interaction between Complexity and Age F(1,46)=5.15,p=.028, with a small effect size (η_P^2 =.10). This effect indicates that word Complexity affected Five-year-olds and Seven-year-olds performance differently. Reaction time on Simple tasks was similar in Five-year-olds (M = 1.21) and Seven-year-olds (M = 1.23), however, Five-year-olds took significantly longer on Complex words (M = 1.50) than did Seven-year-olds (M = 1.34). There was no statistically significant interaction between Similarity and Age F(1,46)=.05,p=.820, η_P^2 =.00. There was an interaction between Complexity and Similarity F(1,46)=10.38,p=.002, η_P^2 =.184. Finally, the three-way interaction between Complexity, Similarity and Age was not significant F(1,46)=.163,p=.689, η_P^2 =.00.

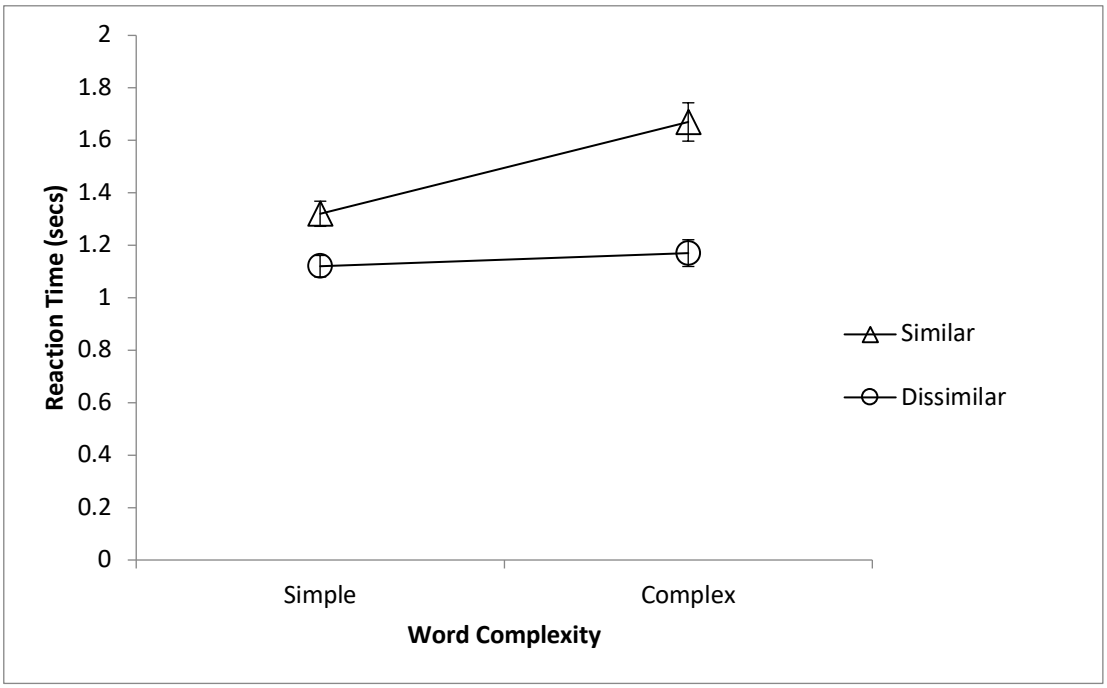


Figure 3.8. Participant reaction time on each of the four Word imitation SRC tasks including SEM error bars in Experiment 4.

3.3.4 Discussion

Experiment 4 investigated the need for IC when resisting verbal imitation. It used four Word imitation SRC tasks: Similar-Simple, Similar-Complex and Dissimilar-Simple, Dissimilar-Complex. Analysis of performance accuracy showed there was a main effect for Similarity but not Complexity. Five- and 7-year-olds accuracy was best on Dissimilar tasks and worst on Similar tasks. There was no interaction of Age. Reaction time analysis showed a main effect for Similarity and Complexity; however, the main effect was bigger for Similarity. There was an interaction for Complexity and Age. All children responded between 1 and 2 seconds after stimulus presentation on each of the four Word SRC imitation tasks. However, the significant interaction effect indicates Five-year-olds took significantly longer responding on Complex words than did Seven-year-olds, and suggests word complexity may be a factor in children's verbal imitation. Overall, however, Experiment 4 results are consistent with the proposal that

similarity determines difficulty. That is, the more alike words are, the more difficult it is to resist verbal imitation.

3.4 Experiment 5

3.4.1 Introduction

Experiment 4 results were mixed. They showed accuracy was best and reaction time was fastest when stimuli and responses were dissimilar. They also showed an interaction between Dissimilarity and Complexity: children's reaction time is greater the more complex and similar words are. These results support the proposal that the amount of word similarity determined the difficulty with resisting verbal imitation: words that were less alike were easier to resist. Experiment 4 results are therefore consistent with the Dissimilarity account of verbal imitation.

However, it is possible Experiment 4 results were caused by a confound: Similar-Complex condition Word pairs were actually more similar (e.g. /c/r/a/b/ and /g/r/a/b/) than the Similar-Simple condition Word pairs (e.g. /b/ee/ and /k/ey/). Similar-Complex words were similar on 3 out of 4 (75%) of phonemes, but Similar-Simple words were similar on only 1 out of 2 (50%) of phonemes (e.g. /b/ee/). In Experiment 5, I therefore varied the similarity of words to test whether similarity determined difficulty. I used four Word imitation tasks. Words contained zero phonemes, one phoneme, two phonemes or three phonemes that were the same. Table 3.3 shows the eight Word pairs used. Under the Word Dissimilarity hypothesis, it is harder to resist imitating when the stimulus and response are similar than

when they are dissimilar. It predicts the Word conditions will be harder the more similar the stimuli and responses are.

Table 3.3. The eight Word conditions containing 0,1,2 or 3 phonemes used in Experiment 5.

	0/4	1/4	2/4	3/4
Set 1	Sink/Crawl	Snack/Clock	Stick/Click	Slap/Clap
Set 2	Bend/Falls	Bread/Find	Bring/Fling	Bright/Fright

3.4.2 Methods

Participants

Study participants (N=57) consisted of 27 children aged 5-years-old: 13 female, and 28 children aged 7-years-old: 14 female. Children were recruited from two primary schools located in a mid-sized town in a semi-rural county in the East of England. All children spoke English as their first language. No children were reported as having any learning or educational problems.

Design

A repeated measures design was used. The independent variable was phoneme similarity. Participant accuracy and reaction time were the dependent variables.

Materials

Verbal responses were recorded using the same audio program and equipment used in Experiments 3 and 4. Eight stimulus response word conditions were created. Word conditions contained two words with different onset but identical rhyme. Words varied in their similarity and comprised of zero, one, two or three phonemes that were the same.

Procedure

SRC tasks used the same if-A-then-B/if-B-then-A rule structure as Experiment 4 (see Table 3.2). Each SRC task comprised four practice trials (order ABAB) and sixteen test trials in a pseudorandom order (ABBABAABBABAABABABBA). Children took part in two sessions of approximately 5-10 minutes in duration. SRC responses were counterbalanced within each group which produced 24 orders overall. SRC response order was randomly allocated to each child.

Prior to beginning the SRC tasks children were asked to show that they could make the verbal gesture required. Children who were unable to voice the response entirely or correctly were prompted and/or corrected on their pronunciation. Children who were unwilling or unable to make the correct verbal gesture were deemed unable to take part in the SRC task and were not considered for further inclusion in the SRC task practice and test sessions. Children who successfully voiced the required verbal gesture practiced doing so along with the experimenter.

The rules of the game were verbally provided in the same manner as in Experiment 4. For example, the experimenter said to each child: 'When I say 'Bright' (pointing to his mouth), then you say 'Fright' (pointing to the child's mouth), and when I say 'Fright' (pointing to his mouth), you say 'Bright' (pointing to the child's mouth). When the experimenter had received confirmation that the child understood the rules of the game, four practice trials began. During practice trials participants were provided with feedback; the experimenter corrected incorrect responses and confirmed correct responses. Children who failed to get at least three

practice trials correct during the first set of four practice trials repeated the practice trial procedure. Children who did not successfully complete a second set of practice trials were omitted from further involvement in the test session. Upon successful completion of four practice trials children were invited to play the game 'for real' and told that they would receive a sticker at the end of the game. Prior to playing the game 'for real' the experimenter informed the child one final time of the game rules. The test trials then began.

During test trials no feedback was provided for incorrect responses, however, a confirmatory response of 'good' or 'well done' was given by the experimenter for all responses. Upon completion of the 16 test trials children were told that they had played a great game and were invited to pick a sticker of their choosing to keep. At the end of session one children were thanked by the experimenter for taking part and asked if they would like to play another silly game. Upon completion of the second SRC task the nursery school employee then returned the child to the main playroom.

3.4.3 Results

Accuracy

Total correct accuracy scores were calculated for 5- and 7-year-olds for each word imitation SRC task, summed, and converted to form a percentage (see Figure 3.9). Five-year-olds accuracy was greatest on Zero Phonemes Task (97.6%) and worst on Three Phoneme Task (81.4%). Seven-year-olds accuracy was greatest on Zero Phoneme Task (98.6%) and worst on Three Phoneme Task (90.4%).

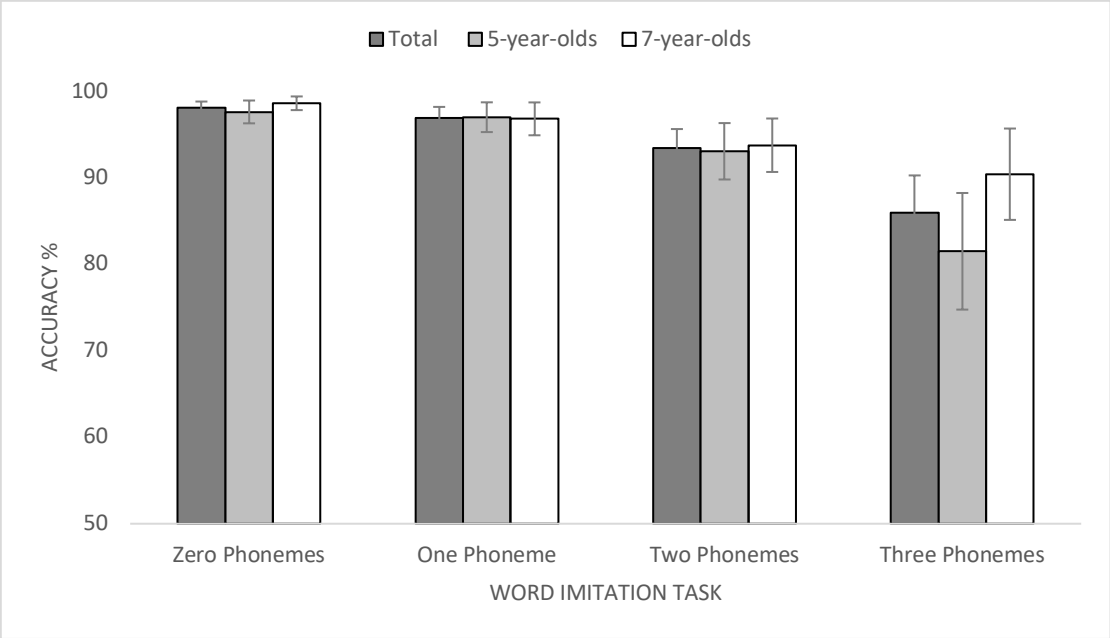


Figure 3.9. Percentage accuracy of four Word imitation SRC conditions including SEM error bars in Experiment 5.

A one-way repeated measures ANOVA was conducted to compare scores on the four Word Phoneme tasks. Mauchly's test of sphericity indicated that the assumption sphericity had been violated $\chi^2(2) = 82.56, p<.001$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .517$). The results showed there was a statistically significant effect of SRC task $F(1.55,82.26)=11.89, p<.001$; however there was a small effect size (η_P^2=.18). Post hoc tests using a Bonferroni correction showed that there was significant differences between the Zero phoneme and Two phoneme tasks (p=0.10); Zero phoneme and Three phoneme (p= <.001); and One phoneme and Three phoneme task. Further tests of within subjects contrasts showed that the four tasks were significantly different from one another in the linear trend $F(1,53)=23.48, p<.001$; and the effect size was small-medium (η_P^2=.31).

A one way repeated measures ANOVA was also conducted to investigate effect of age on Word Phoneme task accuracy. Mauchly's test of sphericity indicated that the assumption sphericity had been violated $\chi^2(5) = 78.61, p<.001$, $\eta_P^2=.33$ therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .52$). There was a significant effect of accuracy $F(1.57, 81.73)=12.40, p<.001$; however, there was a small effect size ($\eta_P^2=.19$). There was no significant effect of age $F(1, 52)=2.37$, $p=.130$, $\eta_P^2=.04$.

Reaction Time

Reaction times were calculated for all 5- and 7-year-olds on each of the four Word Imitation SRC tasks. Reaction times were then summed and divided by the number of participants to create an average (see Fig 3.10). Five-year-olds reacted fastest on the Zero Phoneme word task (.69 secs) and slowest on the Three Phoneme word task (.82 secs). Seven-year-olds reacted fastest on the Zero Phoneme word task (.67 secs) and slowest on the Three Phoneme word task (.74 secs).

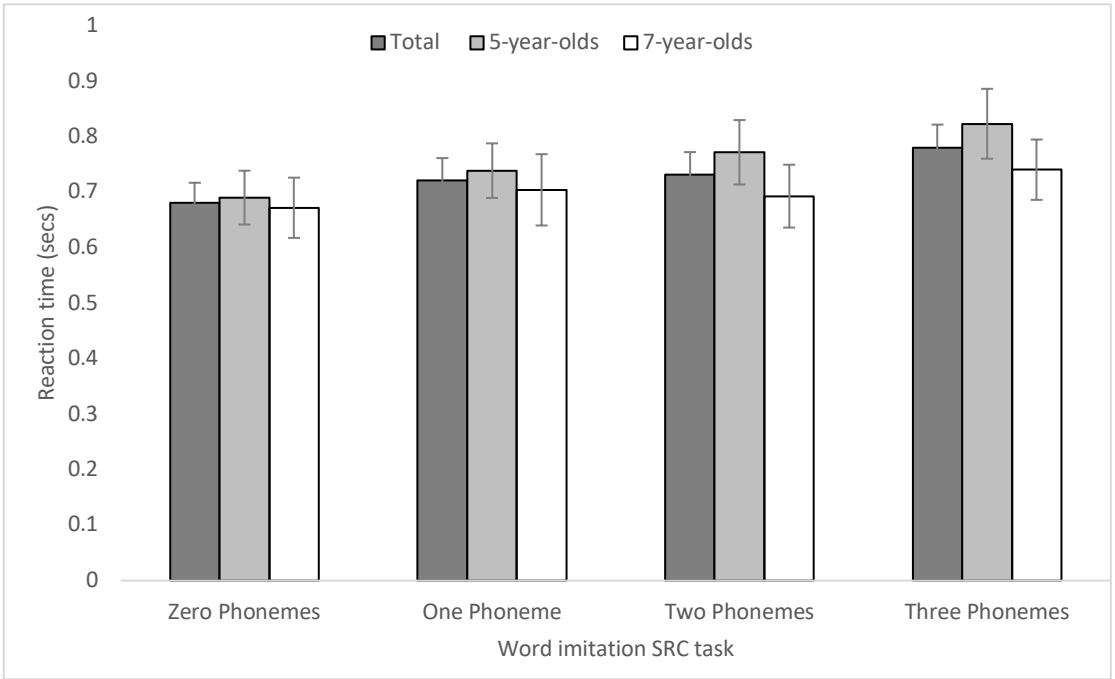


Figure 3.10. Reaction time of four word imitation SRC tasks including SEM error bars in Experiment 5.

A one-way repeated measures ANOVA compared reaction times on the four Word Phoneme SRC tasks. Mauchly's test of sphericity indicated that the assumption of sphericity had not been violated $\chi^2(5) = 8.20$, p=.145. The results showed there was no statistically significant effect of SRC task F(3,156)=2.01, p=.116, η_P^2=.04. Further tests of within subjects contrasts, however, showed that the four tasks were significantly different from one another in the Linear trend F(1,52)=4.84, p=.032, η_P^2=.09.

A one way repeated measures ANOVA was also conducted to investigate effect of age on Word Phoneme task reaction time. Mauchly's test of sphericity indicated that the assumption sphericity had not been violated $\chi^2(5) = 7.99$, p=.157, η_P^2=.33. There was a significant effect of reaction time F(3, 153)=2.04,p=.110; however, there was a small effect size (η_P^2=.04). There was no significant effect of age F(1, 51)=.61, p=.437, η_P^2=.01.

3.4.4 Discussion

Experiment 5 investigated automaticity in verbal imitation. It used four Word imitation tasks. Words contained zero, one, two or three phonemes that were similar. Under the Word Dissimilarity hypothesis, it is easier to resist verbal imitation when the stimulus and response are dissimilar. It predicts Word conditions will be harder the more similar the stimuli and responses are.

Statistical analysis of performance showed 5-year-olds and 7-year-olds' accuracy was best on the zero phoneme task and worst on the three phoneme task. Reaction time analysis showed 5-year-olds and 7-year-olds were fastest on the zero phoneme task and slowest on the three phoneme task. As a result, Experiment 5 data support the Dissimilarity account of verbal imitation, and are consistent with the proposal that similarity determines difficulty. That is, the more alike words are, the more difficult it is to resist verbal imitation.

3.5 General Discussion

The three experiments reported in this chapter investigated the need for IC when resisting verbal imitation in SRC tasks. Specifically, Chapter 3 explored whether the complexity or dissimilarity of stimuli and responses makes verbal imitation easy for children to resist. In Experiment 3 I used three Verbal imitation tasks; Dissimilar-Complex (e.g. hear 'hand' say 'water', hear 'water' say 'hand'), Dissimilar-Simple (e.g. hear 'shoe' say 'bee, hear 'bee' say 'shoe') and two Similar-Complex conditions (e.g. hear 'clown' say 'cloud', hear 'cloud' say 'clown' or hear 'sound' say 'round', hear 'round' say 'sound'). Under the Word Complexity hypothesis, it is harder to resist imitating Simple words than Complex words. It predicts Complex conditions will be easier than Simple conditions. Under the Word Dissimilarity hypothesis, it is harder to resist imitating when the stimulus and response are similar than when they are dissimilar. It predicts Similar conditions would be harder than the Dissimilar conditions. Experiment 3 results showed verbal imitation was easy to resist, and were consistent with a Dissimilarity account: verbal imitation was easier to resist when stimuli and responses were not alike.

In Experiment 4 I continued my investigation of automaticity in verbal imitation tasks. It addressed the concerns that young children struggle to remember SRC task rules by increasing children's age of participation. Experiment 4 tested children aged 5-years-old and 7-years-old. Older children have better IC than younger children and so I included an additional, and more sensitive, measure of performance. In Experiment 4 I tested accuracy and reaction time. Experiment 4 used four Word imitation tasks. As in the previous experiment, under the Word Complexity hypothesis, it is harder to resist imitating simple words than complex words. It predicts Complex conditions will be easier than Simple conditions. Under the Word Dissimilarity hypothesis, it is harder to resist imitating when the stimulus and response are similar than when they are dissimilar. It predicts the Similar conditions would be harder than the Dissimilar conditions. Experiment 4 data were consistent with the Dissimilarity account: it is harder to resist imitating when the stimulus and response are similar than when they are dissimilar. However, there was an interaction between Dissimilarity and Complexity.

Experiment 5 continued to investigate verbal imitation. On reflection, the interaction between Dissimilarity and Complexity in Experiment 4 may have been caused by a confound: Similar-Complex words were more alike than Similar-Simple words. With this in mind, in Experiment 5 I removed this confound. I used four Verbal imitation tasks with different Word pairs containing either zero, one, two, or three phonemes that were the same. Under the Word Dissimilarity hypothesis, it is harder to resist imitating when the stimulus and response are similar than when they are dissimilar. It predicts words are harder to resist imitating the more alike the stimuli and responses are. The results of Experiment 5 were consistent with a

Dissimilarity account: the Word conditions were harder the more similar the stimuli and responses.

Simpson and colleagues (Simpson et al., 2013) first investigated differences between verbal and action imitation. They found that verbal imitation was easier to resist than action imitation. In developing those findings, Simpson & Carroll (2014) also investigated verbal imitation and manual imitation, and showed that verbal imitation was easy for children to resist than manual imitation. Taken together, these findings and data from Chapter 2 suggested a Complexity account of verbal imitation. However, closer inspection of the stimuli and responses used in all this research revealed that they contained a confound. For example, Simpson et al. (2013) used manual actions 'see |finger| make a |fist|, see |fist| point your finger'. These manual actions are physically alike. In contrast, the verbal stimuli and responses used words 'sun' and 'moon'. These words are not phonetically alike; they do not rhyme. It could be that dissimilarity rather than complexity was making verbal imitation easier to resist than manual imitation.

The Dissimilarity account of verbal imitation suggests it is harder to resist imitating when the stimulus and response are phonetically similar than when they are dissimilar. Word imitation is easy to resist when stimuli and responses are not alike. The Dissimilarity account is consistent with the results of Experiments 3, 4 and 5. In each of these experiments the word stimuli and responses differed in their similarity. Performance was better when stimuli and responses were dissimilar. As a consequence of these results, it is likely Dissimilarity does contribute to young children's ease with resisting verbal imitation.

Chapter 4

Why is the Reverse Sort task easier

than the Grass/Snow task?

4.1 Introduction

In Chapter 1 I argued it is children's *intention* to make a response on a Response-Given IC task that means an inappropriate response becomes automatically activated. I also argued *intention* interacts with three SRC task properties to create inappropriate prepotent responses, and so inhibitory demands: (1) inhibited responses are associated with the stimuli, (2) task rules consist of an '*if-stimulus-A-then-response-b/if-stimulus-B-then-response-a'* structure, and (3) participants must apply the *if-A-then-b/if-B-then-a* rule. In the Grass/Snow task (e.g. Simpson & Riggs, 2009) children must point to a 'moon' card when an experimenter says 'sun' and to a 'sun' card when the experimenter says 'moon'. The association of the stimuli with the responses (hear 'sun' point to 'moon' card), the *if-A-then-b/if-B-then-a* rule structure, and children's application of this rule structure mean inhibitory demands are high in the Grass/Snow task. Consequently, tasks that have these properties are difficult for young children (Simpson & Riggs, 2005b).

In this Chapter, I discuss two types of Response-Given SRC tasks: Grass/Snow (e.g. Carlson & Moses, 2001) and Reverse Sort (e.g. Simpson, Lipscombe & Carroll., in prep). Reverse sort SRC tasks (variously called the 'Reverse Sort' task – Lipscombe, this thesis; Simpson et al., in prep; the 'Reversal Shift' task - Perner & Lang, 2002; the 'Reverse Categorization' task – Petersen et al., 2016; and the 'Sorting' task - Bernier et al. 2010), and the Grass/Snow task (e.g. Mahy, Mazachowsky & Pagobo, 2018) are similar in that they both use an If/then ('*if-stimulus-A-then-response-b/if-stimulus B-then-response a')* rule structure. They also both use a manual action to select between one of two locations on each trial (either by putting a cue card in a target tray or by pointing to a target card). Thus, given the similarities between these two

types of SRC task it is surprising that children aged 2-years-old find it easy to resist inappropriate responding on the Reverse Sort tasks than on the Grass/Snow task (Figure 4.1). In contrast, performance on the Grass/Snow task – and other SRC tasks - is poor below 3-years-old. On inspection of Figure 2 from Peterson et al. (2016, p40) it is clear that Reverse Sort tasks (labelled 'Reverse Categorisation' in the figure) are easier than other SRC tasks that involve resisting pointing, imitating and naming.

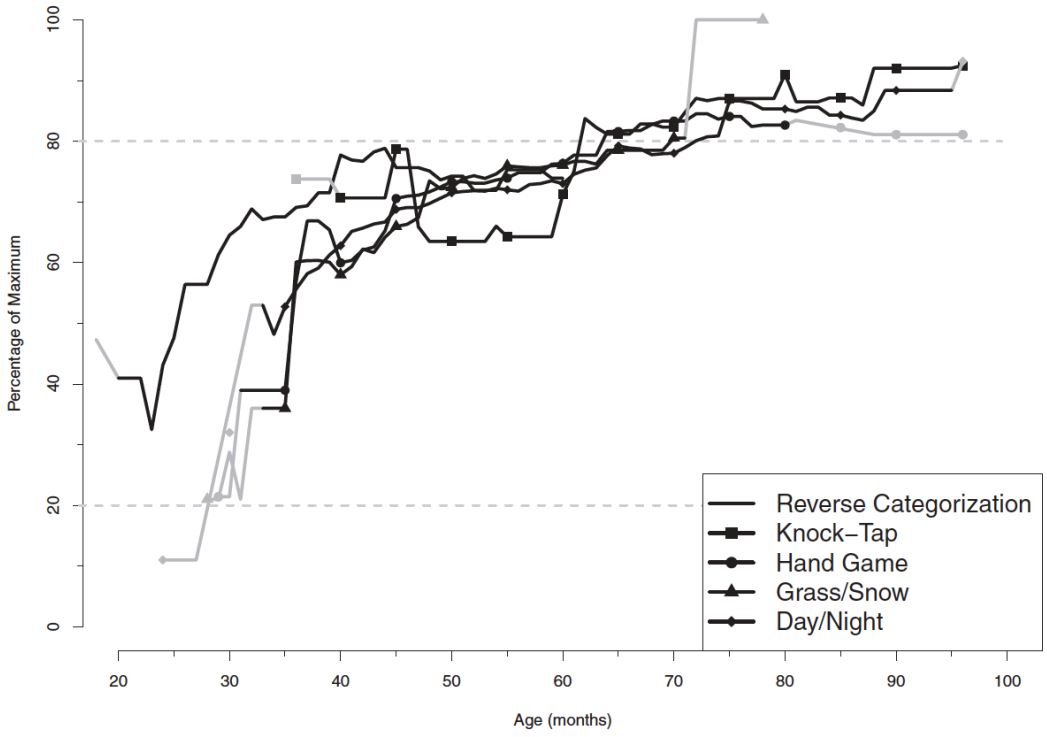


Figure 4.1. Children's average percentage-of-maximum score on 'middle' inhibitory control measures by age (from Peterson et al., 2016).

Despite their similarity to each other, Grass/Snow and Reverse Sort tasks are dissimilar in at least two ways, (1) visual versus verbal cueing: the Grass/Snow task is verbally cued - when the experimenter *says* 'sun' the child points to the 'moon' card, and when they *say* 'moon' the child points to the 'sun' card (Simpson & Riggs, 2009); the Reverse Sort task is visually

cued - when children *see* a 'sun' card they sort it into the 'moon' target tray, and when they *see* a 'moon' card it is sorted into a 'sun' target tray (e.g. Simpson et al., in prep); and (2) is the nature of the response they require children to provide: in Grass/Snow tasks children respond by pointing at target cards, whereas in the Reverse Sort task cue cards are manually sorted into target trays. It seems likely that the difference in performance observed on Grass/Snow and Reverse Sort SRC tasks is related in some way to these differences.

4.1.1. The Grass/Snow task

The Grass/Snow task (e.g. Carlson & Moses, 2001; Simpson & Riggs, 2009) is a commonly used Response-Given SRC task (see Table 4.1, Appendix 2). It is typically used with children aged between 2.5- and 6-years-old (see Peterson et al., 2016). To be successful on Grass/Snow tasks children must point to one of two target images/colours using a pre-identified stimulus-response association that is opposite to an automatically activated, but inappropriate, stimulus-response association. For example, Carlson and Moses (2001) had children point to a white square when the experimenter said 'grass' and point to a green square when the experimenter said 'snow'. Stimuli variants (see Table 4.1) include 'sun' and 'moon' images (Simpson, Riggs & Simon, 2004; Simpson and Riggs, 2009), red and blue paper (Oh & Lewis, 2008 - Experiment 2), and 'Mummy' and 'Child' images (Caughy, Mills, Owen, & Hurst, 2013). Regardless of the difference in stimuli and responses used in each of the Grass/Snow task variants, they have one thing in common: the Grass/Snow task is difficult for young children (e.g. Simpson & Riggs, 2009). Carlson & Moses (2001) first used the Grass/Snow task as one of a battery of IC tasks to confirm the relationship between Inhibitory Control and Theory of Mind. More recent studies, however, have utilised the Grass/Snow task in isolation to

investigate, for example, what makes responses prepotent for young children (Simpson & Riggs, 2009).

Interestingly, there is some inconsistency in the developmental literature concerning the Grass/Snow SRC task, which has led to some tasks being erroneously identified. Cuevas, Hubble, and Bell (2012), for example, used an SRC task which they identified as a variant of the Grass/Snow task. In the 'Mummy' and 'Me' task children are instructed to say 'mummy' when shown an image of themselves, and say 'me' when shown an image of their 'mummy'. As such, this task is clearly more similar to the Day-Night task (e.g. Gerstadt et al., 1994) than the Grass/Snow task (e.g. Carlson & Moses, 2001), as responses were verbal not manual (declarative pointing). And in Rothlisberger, Neuenschwander, Cimeli, Michel, and Roebers (2011) a "Grass/Snow" task required children initially to place images of raindrops on a blue part of a chart and images of snowflakes on a white part; in addition, the sorting rules were reversed whenever the cards depicted a sun or a snowman. Thus, the initial – cue card placing response is more similar to the Reverse Sort task. Further, the reverse rule enacted upon presentation of a sun or snowman image makes the task more similar to the Dimensional Change Card Sort Task (see below) than the Grass/Snow task (e.g. Carlson & Moses, 2001).

4.1.2. The Reverse Sort task and its variants

Reverse Sort tasks are commonly used SRC tasks (see Table 4.1, Appendix 2) that require children to sort objects (e.g. Big and Little Blocks – Carlson, 2005) or picture cards (e.g. Red / Blue and Rabbits / Boats - Albertson & Shore, 2008) according to pre-established rules that are opposite to an automatically activated, but inappropriate, rule. Reverse Sort tasks are useful for children aged between 1.5- to 5-years-old (see Peterson et al. 2016). In their meta-

analysis of 198 studies that utilise IC, Peterson et al. identify three Reverse Sort tasks: two that use If/then rules – the Reversal Shift task (Perner & Lang, 2002) and the Sorting task (Bernier, Carlson & Whipple, 2010); and the Dimensional Change Card Sort task (Frye, Zelazo & Palfai, 1995) - a Reverse Sort task that uses If-If/then (non-SRC) rules (e.g. '*if we are playing the colour game, then if I give you a red pear, then put it into the box with the red apple target* - Kloo and Perner, 2003*)*.

The Reversal Shift task (Perner & Lang, 2002) is a Reverse Sort task consisting of If/then rules. It consists of two phases: a pre-switch phase and post-switch phase. Reversal Shift tasks are single-dimension shift tasks: post-switch sorting is via a within-dimension shift. For example, in the Reversal Shift with Target Cards condition, Perner and Lang (2002 – Experiment 1) had children sort car images to car targets and sun images to sun targets in the pre-switch phase; in the post-switch phase cars were sorted to suns and suns sorted to cars. Performance on these tasks typically show children of 2-years-old have greatest difficulty with the post-switch element of the task (e.g. Carlson, 2005).

The Sorting task (e.g. Bellagamba, Laghi, Lonigro, & Pace, 2012; Bernier, Carlson & Whipple, 2010) has the same If/then rules. In the Sorting task objects are sorted by a single dimension in a single sorting phase (although see Experiments 6, 7 and 8, Chapter 4 - this thesis, for a variant of the Sorting task using picture cards). The Sorting task is typically used with children of 2-years-old or younger. In Bernier, Carlson & Whipple (2010), for example, children sorted baby animals into the 'baby box' and adult animals into the 'adult box'. The Sorting task is analogous to the post-switch sorting phase in the Reversal Shift (e.g. Perner & Lang, 2002)

task: an object must be sorted according to an If/then rule and then placed into the appropriate sorting tray.

The Dimensional Change Card Sort task (Frye, Zelazo & Palfai, 1995) is a Reverse Sort task consisting of hierarchical if-if/then rules. It is used with children aged 3- to 5-years-old although non-standard versions of the task can be used with children up to 7-years-old (Zelazo, 2006). In the Dimensional Change Card Sort task cue cards are first sorted by one dimension in a pre-switch phase and then by a second dimension in a post-switch phase. In Frye, Zelazo and Palfai (1995), for example, cue cards consisting of blue triangles and red circles are sorted by shape in the pre-switch phase and then by colour in the post-switch phase. Other shape stimuli used in Dimensional Change Card Sort tasks, include: rabbits and boats (Albertson & Shore 2008; Fizke, Barthel, Peters, & Rakoczy, 2014) and dogs and birds (Kloo, Perner, Kerschhuber, Dabernig, & Aichhorn, 2008). However, most studies use the same colours: red and blue (e.g. Albertson & Shore, 2008), although Carlson and Moses (2001) also used yellow and green. Variants of the Dimensional Change Card Sort task (e.g. Carlson, Mandell and Williams, 2004; Hammond, Müller, Carpendale, Bibok, & Liebermann-Finestone, 2012) use three dimensional objects rather than picture cards. Carlson et al. (2004), for example, had children sort big and little blocks into big and little buckets. In the pre-switch phase big blocks were sorted into big buckets and little blocks into little buckets; in the post-switch phase big blocks were sorted into little buckets and little blocks into big buckets.

The Dimensional Change Card Sort task (Frye, Zelazo & Palfai, 1995) tests cognitive flexibility - the adaptive and rapidly-engaged ability to respond to dynamic changes in environmental stimuli (e.g. Chevalier, Sheffield, Nelson, Clark, Wiebe, & Espy, 2012). In this respect it is

different to the Sorting task (Bernier, Carlson & Whipple, 2010) and Reversal Shift task (Perner & Lang, 2002), which test the more basic executive function of inhibitory control. The Dimensional Change Card Sort (Frye, Zelazo & Palfai, 1995) task's two phases contain an extra dimensional shift: a pre-switch phase in which a picture card is sorted by one dimension (e.g. shape) and a post-switch phase that requires children to sort via a second dimension (e.g. colour). Thus, to be successful on the task children must show cognitive flexibility if they are to be able to shift from sorting by one dimension to the other. (Although, more recently Carroll, Blakey and Fitzgibbon, 2016, suggest Cognitive Flexibility is more than simply the ability to flexibly shift. It also incorporates the abilities to: update task rules, attend selectively to different aspects of a stimulus, resolve conflict between responses, and coordinate and use all the skills at the same time). Typically, Dimensional Change Card Sort task performance shows children aged 3-years-old are cognitively inflexible: they tend to perseverate (e.g. Carlson & Moses, 2001; Frye, Zelazo & Palfai, 1995; Zelazo, Frye & Rapus, 1996) i.e. they continue to sort in the post-switch phase by the dimension used in the pre-switch phase. However, children aged 4-years-old tend to find the post-switch rule much easier (Zelazo, Frye & Rapus, 1996). As a result, the increase in accuracy observed between ages 3- to 4-years-old is argued to be a function of children's developing cognitive flexibility as they get older.

4.1.3 Explaining why the Reverse Sort task is easier to resist than the Grass/Snow task.

A defining difference between Reverse Sort and Grass/Snow tasks is the way in which stimuli are cued: in the Grass/Snow SRC task stimuli are cued verbally - when an experimenter says 'moon' the child must point to the 'sun' target image (Simpson & Riggs, 2009); in contrast,

Reverse Sort SRC tasks are cued visually - when an experimenter produces a 'sun' cue card the child must sort it into the 'moon' target tray (Simpson et al., in prep).

I now discuss two possible explanations of why children find the Reverse Sort task easier than the Grass/Snow task: (1) Conceptualisation, and (2) Delay. Both these explanations relate to the different ways that children respond in the two tasks. Under a Conceptualisation account, children use an *IC-avoiding* conceptualisation to reduce the inhibitory demands of the Reverse Sort task. Delay, on the other hand, works simply because slowing down responding reduces a task's inhibitory demands.

A first possible explanation for why children find the Reverse Sort task easier than the Grass/Snow task relates to conceptualisation. In Chapter 1 I argued that SRC tasks are difficult when children use '*if-stimulus-A-then-response-b/if-stimulus B-then-response a'*, as this rule structure ensures that a task has high inhibitory demands. However, it follows that inhibitory demands may be reduced if children can conceptualise the task in a way that avoids using this *IC-requiring* rule (Simpson & Carroll, 2018). I suggest that this may be what is happening in the Reverse Sort task: children are using an *IC-avoiding* rule instead of an *IC-requiring* rule (If/then rule). For example, in the Reverse Sort task, children may simply choose to 'point to the other card' rather than employ the *'if-stimulus-A-then-response-B/if-stimulus B-then-response A'*. Conceptualising the task's rules in an *IC-avoiding* way means inhibitory demands are reduced and children do not need to rely on their weak IC to be successful.

A second explanation for why the Reverse Sort task is easier than the Grass/Snow task relates to delay. In the Grass/Snow task children use their finger to point to a target image that is

opposite of the verbal cue (e.g. Simpson & Riggs, 2009). In Reverse Sort tasks (e.g. Simpson et al., in prep), however, children must take hold of a cue card (given by the experimenter) and place it in a target card tray. In this way, there is a natural slowing of responding inherent in making responses in Reverse Sort tasks, that is not present in Grass/Snow tasks. In Reverse Sort tasks children must wait for the cue card to be handed to them, take hold of it, and then place it in a target card tray: all of this takes time. The set of movements required in the Reverse Sort task seems likely to take longer to enact than simply pointing to a target image as required in the Grass/Snow task. At present there is no data on how long the sorting and point responses take. However, delaying responding has been shown to improve performance in other inhibitory tasks (Gerstadt et al., 1994; Ling et al., 2016; Simpson et al., 2012; Simpson & Riggs, 2007; Simpson et al., in prep). So if children do respond more slowly in the Reverse Sort task it seems likely that this would lead to better performance on that task.

4.1.4. The studies in this chapter

The three experiments reported in this chapter built on research with young children that showed differences in performance on Reverse Sort and Grass/Snow tasks (see Peterson et al., 2016). In Chapter 4 I explored why inhibiting sorting is easier than inhibiting pointing.

In Experiment 6 I investigated task conceptualisation in SRC tasks. Developing the research findings of Simpson and Carroll (2018), I explored whether children use an *IC-avoiding* conceptualise to reduce inhibitory demands of the Reverse Sort task. Simpson and Carroll (2018) suggested that conceptualisation of a task's rules is central to the creation of that task's inhibitory demands. *IC-requiring* SRC tasks are those that utilise *if-A-then-b, if-B-then-*

a rules, for example, in the Grass/Snow task children must point to a 'sun' card when the experimenter says 'moon', and point to a 'moon' card when the experimenter says 'sun'. *IC-avoiding* SRC tasks are any tasks that do not use this if/then rule structure. If children can conceptualise an SRC task in any other way, then it will have reduced inhibitory demands, and so improve performance on the task.

In Experiment 6, I investigated the possibility that performance was better on the Reverse Sort task than the Grass/Snow task because children (or at least some children) use an *IC-avoiding* rule when performing the Reverse Sort task. One difference between the mode of responding in the Reverse Sort task and the Grass/Snow task is that children can see both the cue card that they are holding, and the target card attached to the tray into which the cue card is sorted. It may be that, being able to *see* both the cue and target cards, children become aware that on every trial they are in some sense 'doing the same thing'. That is, on every trial children are making a pair which contains both types of card used in the task: for example, making a pair which contains the both the 'sun' and 'moon' cards. If children conceptualise the task as 'make-a-pair' containing the two types of card, then they avoid the necessity of using the *IC-requiring* 'if/then' rules. Using an *IC-avoiding* 'make-a-pair' rule would eliminate the Reverse Sort task's inhibitory demands, and so make it easy for young children. However, the results of Experiment 6 did not support this proposal. The data were not consistent with children using an *IC-avoiding* 'make-a-pair' rule on the Reverse Sort task.

In Experiment 7 I again investigated conceptualisation in SRC tasks. Under Conceptualisation, conceptualising task rules in an *IC-avoiding* 'make-a-pair' way makes the Reverse Sort task easier than the Grass/Snow task. Importantly, however, the use of a 'make-a-pair' rule in the

Reverse Sort task may be facilitated by the visual presentation of the cue cards: children always see they are making the same pair on each trial because they always see the cue cards that are being presented; as such, they can then employ a 'make-a-pair' rule (e.g. always combine the apple and the horse cards). In Experiment 7 I introduced a Face-Down Reverse Sort task which would prevent children conceptualising the task in an *IC-avoiding* way i.e. 'make-a-pair'. In the Face-Down Reverse Sort task it was not possible for children to see that they were combining the two same cards on each trial. I hypothesised that the Reverse Sort task is easier than the Grass/Snow task because children are using an *IC-avoiding* conceptualisation ('make-a-pair' rule) irrespective of how cue cards are introduced. However, the results of Experiment 7 did not support my hypothesis: the data were again inconsistent with children using an IC-avoiding 'make-a-pair' rule on the Reverse Sort task.

In Experiment 8 I investigated why the Reverse Sort task is easier than the Grass/Snow task. Reverse Sort and Grass/Snow tasks differ in the way responses are provided: in the Reverse Sort task children must place a cue card in a target card tray; in the Grass/Snow task child simply point their finger at the target image. Under a Delay account, the Reverse Sort task is easier than the Grass/Snow task because the whole process of sorting cards takes longer than pointing a finger, particularly because – in the Reverse Sort task - children see the cue card and then must wait while it is handed to them. I hypothesised that the Reverse Sort task would be easier than the Grass/Snow task because children respond more slowly when sorting cards, and delaying responding reduces inhibitory demands. The results of Experiment 8 supported my hypothesis: the Reverse Sort task was easier than the Grass/Snow task because children do respond more slowly when sorting cards and delaying responding reduces inhibitory demands.

4.2. Experiment 6

4.2.1. Introduction

In Chapter 1, I reported research by Simpson and Carroll (2018) that suggested Conceptualisation is key to the establishment of inhibitory demands in SRC tasks. SRC tasks use If/then rules. Conceptualising a task as having If/then rules is an *IC-requiring* conceptualisation, and means the task will have inhibitory demands. Conceptualising SRC task rules in any other way is an *IC-avoiding* conceptualisation, and means inhibitory demands are reduced. In their study, Simpson and Carroll (2018) obtained evidence that 'all' children in a Marker task and 'some' children in a Point-cued task utilised an *IC-avoiding* conceptualisation. It is possible that children also use an *IC-avoiding* conceptualisation in the Reverse Sort task, thus eliminating the need for them to use IC.

In Experiment 6 I investigated Conceptualisation in four SRC tasks. I explored whether the Reverse Sort task is easier than the Grass/Snow task because children conceptualise it using an *IC-avoiding* 'make-a-pair' rule rather than using an *IC-requiring* 'If/then' rule. Experiment 6 used two versions of the Grass/Snow task (Standard Grass/Snow and Marker Grass/Snow), and two versions of the Reverse Sort task (Standard Reverse Sort and Make-a-pair Reverse Sort). The two Grass/Snow tasks were used as indicators of low performance (Standard Grass/Snow) and high performance (Marker Grass/Snow). They each used one picture card of a horse and one picture card of an apple: the Standard Grass/Snow task used the rules 'Hear |horse| point to |apple| card, hear |apple| point to |horse| card', and the Marker Grass/Snow task used the rules 'See marker on |horse| point to |apple| card, see marker on |apple| point to |horse| card'. The two Reverse Sort tasks used the same horse and apple

stimuli: the Standard Reverse Sort task used the rules 'If you get a |horse| card then put it with the |apple| card, if you get an |apple| card then put it with the |horse| card', and the Make-a-pair Reverse Sort task used the rules 'Horses like to eat apples. When I hand you an |apple|, give it to the |horse|, and when I hand you a |horse|, put it with the |apple|. Every time you put the horse and apple together').

A Conceptualisation account suggests that if *all* children use an *IC-avoiding* conceptualisation then performance on the Standard Reverse Sort task is expected to be as good as the Marker task – a task which Simpson & Carroll (2018) showed is easy for young children, with performance at near-ceiling. However, if only *some* children use an *IC-avoiding* conceptualisation then it is expected that telling them to use it on the Make-a-pair Reverse Sort task will improve performance.

4.2.3. Method

Participants

Study participants (N=32) consisted of children aged between thirty-six months and fifty-one months (Mean age = 43 months); 20 female. Children were recruited from nursery schools located in a mid-sized town in a semi-rural county in the East of England. All children spoke English as their first language.

Design

A repeated-measures design was used. Stimulus type (Standard Grass/Snow, Marker, Standard Reverse Sort and Make-a-pair) was the independent variable. Participant accuracy was the dependent variable. Table (4.2) shows the four experimental conditions.

Material

Two black and white images were used: a |horse| image and an |apple| image) (see Figure 4.2). Two laminated picture cards contained either a |horse| picture or a |apple| picture. Each card measured 10cm by 7cm. In the Marker task a wooden star (5cm diameter) was used as a marker.

Procedure

SRC tasks used an *if-A-then-b/if-B-then-a* rule structure. The Standard Grass/Snow task used the rules 'Hear |horse| point to |apple| card, hear |apple| point to |horse| card'. The Marker task used the rules 'See marker on |horse| point to |apple| card, see marker on |apple| point to |horse| card'. The Standard Reverse Sort and Make-a-pair tasks used rules 'Receive |horse| card place on |apple| card, receive |apple| card place on |horse| card'.

Each SRC task comprised four practice trials (order ABAB) and 16 test trials in a pseudorandom order (ABBABAABBABAABAB). Children completed four practice trials before beginning the test trials. Children completed two sessions of approximately 10 minutes in duration across two days. The sessions were not more than ten days apart. SRC tasks were counterbalanced which produced eight orders overall. The two Reverse Sort tasks (Standard Reverse Sort and Make-a-pair) were always in different sessions.

Prior to beginning the SRC tasks children were collected from the main nursery room by a nursery employee and brought to the test room where the experimenter was seated. The experimenter introduced himself to the child and invited them to sit opposite the

experimenter at a low table. All children were accompanied by a nursery employee who was seated close by, but who was instructed not to help children during the testing.

Each child was then asked if they wanted to take part in a 'silly game'. For each SRC task, children were then shown the |horse| and |apple| cards. The experimenter first picked up the |horse| card and asked the child what the image was of. Children who did not know the image or guessed incorrectly were corrected. The experimenter then picked up the |apple| card and repeated the process. When children had been introduced to both images the experimenter explained the game rules.

The Standard Grass/Snow task used rules 'Hear |horse| point to the |apple| card, hear |apple| point to the |horse| card. The Marker task used rules 'See star on |horse| card point to |apple| card, see star on |apple| card point to |horse| card'. In the Standard Reverse Sort task, children were told 'if you get a |horse| card then put it with the |apple| card, if you get an |apple| card then put it with the |horse| card'. In the Make-a-pair task the experimenter explained 'Horses like to eat apples. When I hand you an |apple|, give it to the |horse|, and when I hand you a |horse| put it with the |apple|. Every time you put the horse and apple together'.

To confirm children had understood SRC task instructions they were then asked if they remembered what to do. Children who remained unsure of the response that they should provide were again informed of the game rules. Once the experimenter had received confirmation that the child understood the rules of the game the experiment began with four practice trials. During practice trials children were provided with feedback; the experimenter

corrected incorrect responses and confirmed correct responses. Children who failed to get at least three practice trials correct repeated the four practice trials. Children who did not successfully complete a second set of practice trials were omitted from further involvement in the test session. Children who did successfully complete the practice trials then completed 16 test trials. No feedback was given during test trials.

Upon completion of the 16 test trials children were told that they had played a good game and were invited to pick a sticker of their choosing to keep. At the end of game one participants were invited to play another 'silly game' for which they would receive another sticker. At the end of game two children picked a sticker, were thanked by the experimenter for taking part, and asked if they would like to play another set of games on another day. Children were then returned to the main play room by the nursery school employee.

Table 4.2. The four SRC tasks used in Experiment 6.

Task	Rules
Standard Reverse Sort	If you get a |horse| card then put it with the |apple| card, if you get an |apple| card then put it with the |horse| card.
Make-a-pair Reverse Sort	Horses like to eat apples. When I hand you an |apple|, give it to the |horse|, and when I hand you a |horse|, put it with the |apple|. Every time you put the horse and apple together.
Marker Grass/Snow	See star on |horse| card point to |apple| card, see star on |apple| card point to |horse| card.
Standard Grass/Snow	Hear |horse| point to the |apple| card, hear |apple| point to the |horse| card.

Figure 4.2. The Horse and Apple images used in Experiment 6.

4.2.4. Results

Total correct responses were summed for each SRC task and converted to form a percentage score (see Fig 4.3). Overall performance was not similar across each of the four SRC tasks. Children were more accurate on the Marker Grass/Snow task than any other task. However, performance was similar on the Standard Reverse Sort and Make-a-pair Reverse Sort tasks. Accuracy on the Standard Grass/Snow task was lowest of all tasks.

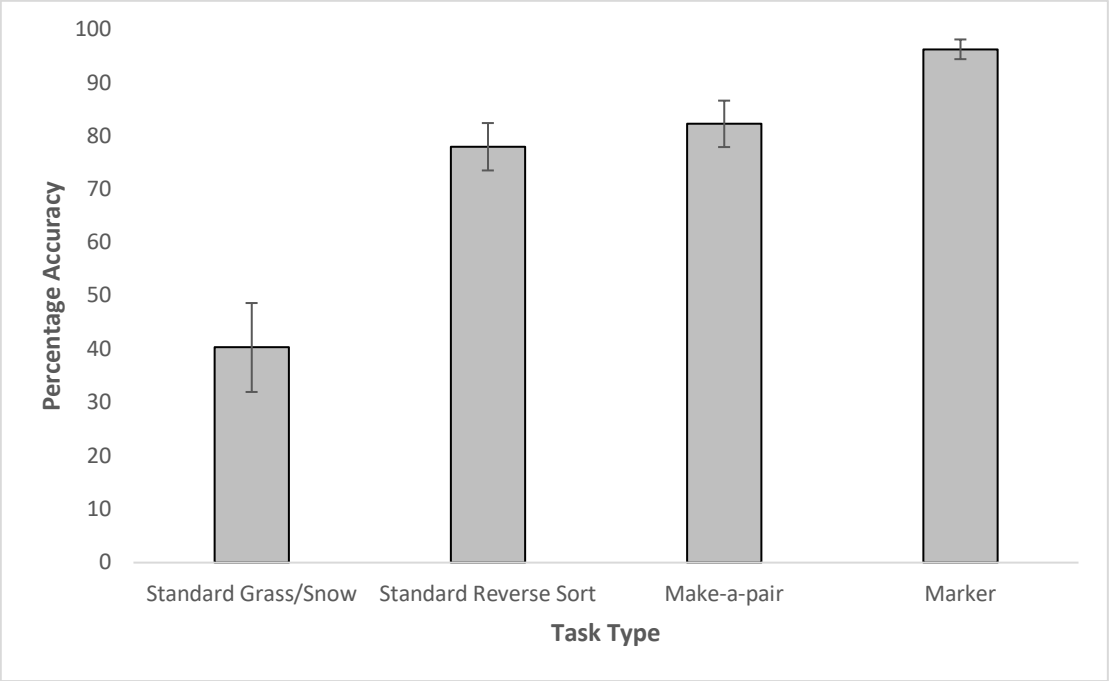


Figure 4.3. Performance accuracy of four SRC tasks including SEM error bars in Experiment 6.

First analysis of SRC data investigated for differences across each of the four SRC tasks. A within-participant one-way ANOVA used Standard Grass/Snow, Marker Grass/Snow, Standard Reverse Sort and Make-a-pair Reverse Sort tasks and as independent variables. Mauchly's test indicated assumptions of sphericity had been violated, $\chi^2(5)=22.79, p<0.01$ therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε =.65). Results showed a statistically significant difference between the four tasks $F(1.94, 60.33)= 73.37$, p<.001; and a medium-large effect size (η_P^2= .70).

Further analysis of the data compared the Standard Reverse Sort and Marker Grass/Snow tasks; and the Standard Reverse Sort and Make-a-pair Reverse Sort tasks. A Paired samples t-test showed there was no statistically significant difference between Make-a-pair Reverse Sort and Standard Reverse Sort tasks $t(31)= -1.46$, p=.155; 95% CI (10% - 17%). The effect size for this analysis (d = 0.26) was found to be small (Cohen, 1988). Correlational analysis showed

a medium positive correlation between the two tasks r(32)=0.43, p=0.015. Performance on each task is mirrored in performance on the other task. A Paired samples t-test showed there was a statistically significant difference between Standard Reverse Sort and Marker tasks t(31)= -6.54, p<.001, 95% CI (13% - 24%). Using the Cohen's D (Cohen, 1988) effect size convention, the effect size for this analysis (d = 1.15) was found to be large. Correlational analysis showed a weak positive correlation between the two tasks r(32)=0.18,p<.05.

I next investigated the effect of task order on SRC task accuracy. Mauchly's test indicated assumptions of sphericity had been violated, $\chi^2(5)=19.60$,p<.001 therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε =.63). There was no significant main effect of task order F(13.21,45.29)=.48,p=.926, η_P^2=.12. No difference between the order in which SRC tasks are completed and children's performance on SRC tasks exists.

4.2.5. Discussion

Experiment 6 investigated Conceptualisation in SRC tasks. I used four SRC tasks: two Grass/Snow (Standard Grass/Snow and Marker Grass/Snow) and two Reverse Sort (Standard Reverse Sort and Make-a-pair Reverse Sort) to investigate whether using an *IC-avoiding* 'make-a-pair' conceptualisation enables children to reduce the inhibitory demands of the Reverse Sort task. I hypothesised that the Reverse Sort task would be easier than the Grass/Snow task because children conceptualise it as 'make a pair' of cards (an *IC-avoiding* conceptualisation) rather than following the If/then rule (an *IC-requiring* conceptualisation).

As expected, statistical analysis of Reverse Sort data in Experiment 6 showed performance on the Marker Grass/Snow task (low inhibitory demands) was near-ceiling level and performance on the Standard Grass/Snow task (high inhibitory demands) was poor. The Standard Reverse Sort and Make-a-pair Reverse Sort tasks (intermediate inhibitory demands) showed good performance. However, my hypothesis was not supported: performance did not improve when children were encouraged to conceptualise the Reverse Sort task in an *IC-avoiding* way. If *all* children used an *IC-avoiding* conceptualisation then performance on the Standard Reverse Sort task should have been as good as performance on the Marker task. However, my results showed that performance on the Standard Reverse Sort was not as good as on the Marker task – and suggests not *all* children were using an IC-avoiding conceptualisation. Further, if only *some* children use an *IC-avoiding* conceptualisation then telling them to use it on the Make-a-pair Reverse Sort task should have improved performance over-and-above performance on the Standard Reverse Sort task. However, results showed no difference in performance on the Standard Reverse Sort and Make-a-pair Reverse Sort tasks – and suggest that telling children to use an *IC-avoiding* 'make-a-pair' conceptualisation did not increase their use of it.

4.3. Experiment 7

4.3.1 Introduction

Experiment 6 investigated Conceptualisation in SRC tasks. The results showed I was unable to increase the use of an *IC-avoiding* conceptualisation in the Make-a-pair Reverse Sort task. The data did not support my hypotheses that performance would improve when the Reverse Sort task was introduced in an *IC-avoiding* way. As such, Experiment 6 results did not support a

Conceptualisation account (e.g. Simpson & Carroll, 2018) of why the Reverse Sort task is easier than the Grass/Snow task. Despite these findings, it was still possible that preschooler's accuracy on the Reverse Sort task *was* improved by the use of the *IC-avoiding* 'make-a-pair' conceptualisation. This could occur if only *some* children used an *IC-avoiding* conceptualisation, and our efforts to increase its use (by instructing children to do so in the Make-a-pair Reverse Sort task had failed). It was this possibility I tested in Experiment 7.

In Experiment 7 I continued my investigation of why the Reverse Sort task is easier than the Grass/Snow task. Experiment 7 used four SRC tasks consisting of an *if-A-then-b/if-B-then-a* rule to investigate whether children's ease with the Reverse Sort task is because they use an *IC-avoiding* conceptualisation: two Grass/Snow SRC tasks (Standard Grass/Snow and Marker Grass/Snow), and two Reverse Sort SRC tasks (Standard Reverse Sort and Face-Down Reverse Sort). The Standard Grass/Snow and Marker Grass/Snow tasks were again included to provide reference points for low and high performance.

The Standard Reverse Sort and Face-Down Reverse Sort tasks differed in the way in which the response was cued. In both Reverse Sort tasks cue cards are used, however, in the Standard Reverse Sort task children see what the image on the cue card is because the card is presented to them with the image facing upwards, whereas in the Face-Down Reverse Sort task children cannot see the image on the card as it is presented to them facing downwards. Thus, in the Standard Reverse Sort task, cue cards are presented *visually:* children *see* the image on the cue card before it is handed to them and they then place it in the appropriate sorting tray; this means children can always see that they are making a pair of cards on every trial – and so they may spontaneously conceptualise the task in an *IC-avoiding* 'make-a-pair' way.

However, in the Face-Down Reverse Sort task cue cards are presented *verbally*: children only *hear* what the image on the cue card is before it is handed to them, and they then place it in the appropriate sorting tray; this means children cannot *see* that they are making a pair - and so are very unlikely to spontaneously conceptualise the task in this way. It seems probable that children need to be able to see that they are making a pair in order for an *IC-avoiding* conceptualisation to be adopted; when they cannot see the cards, they do not realise they are making a pair. Thus, it is the inability to see the card on the Face-Down Reverse Sort task that prevents children from inferring the *IC-avoiding* 'make-a-pair' rule. Table (4.3) shows the four experimental tasks. I hypothesised that the Reverse Sort task is easier than the Grass/Snow task because children are using an *IC-avoiding* 'make-a-pair' conceptualisation. If so, then accuracy on the Face-Down Reverse Sort task would be lower than the Standard Reverse Sort task. This would occur because fewer children would use the *IC-avoiding* 'make-a-pair' conceptualisation in the Face-Down Reverse Sort task.

4.3.2. Method

Participants

Study participants (N=32) consisted of children aged between thirty-six months and fifty-one months (Mean age = 43 months); 17 female. Children were recruited from nursery schools located in a mid-sized town in a semi-rural county in the East of England. All children spoke English as their first language.

Design

A repeated-measures design was used. Stimulus type (Standard Grass/Snow, Marker Grass/Snow, Standard Reverse Sort and Face-Down Reverse Sort) was the independent variable. Participant accuracy on the 16 test trials was the dependent variable.

Materials

Two black and white images were used: a |sun| image and a |moon| image) (see Figure 4.4). Two laminated picture cards contained either a |sun| image or a |moon| image. Each picture card measured 14cm by 10cm. In the Marker Grass/Snow task a gold star (5cm diameter) was used as a marker. In the Standard Reverse Sort and Face-Down Reverse Sort tasks, two sorting trays measuring 15cm by 23cm were used. Each sorting tray was clearly labelled with either a |sun| or a |moon| image positioned in the centre-front of the tray.

Procedure

SRC tasks used an *if-A-then-b/if-B-then-a* rule structure (see Table 4.2). The Standard Grass/Snow task used the rules 'Hear |sun| point to moon, hear |moon| point to sun'. The Marker Grass/Snow task used rules 'See marker on |sun| point to |moon|, see marker on |moon| point to |sun|'. The Standard Reverse Sort task used rules 'See |sun| card place in |moon| card tray, see |moon| card place in |sun| card tray'. The Face-Down Reverse Sort task used rules 'Hear |sun| place in |moon card| tray, hear |moon| place in |sun| card tray'.

Each SRC task comprised four practice trials (order ABAB) and 16 test trials in a pseudorandom order (ABBABAABBABAABAB). Children completed four practice trials before beginning the test trials. Children completed two sessions of approximately 10 minutes in duration across

two days. The sessions were not more than ten days apart. SRC tasks were counterbalanced which produced eight orders overall. The two Reverse Sort tasks (Standard Reverse Sort and Face-Down Reverse Sort) were always in different sessions.

Prior to beginning the SRC tasks, children were collected from the main nursery room by a nursery employee and brought to the test room where the experimenter was seated. The experimenter introduced himself to the child and invited them to sit opposite the experimenter at a low table. All children were accompanied by a nursery employee who was seated close by, but who was instructed not to help children during the testing.

Each child was asked if they wanted to take part in a silly game. For each SRC task, children were then shown the |sun| and |moon| cards. The experimenter first picked up the |sun| card and asked the child what the image was of. Children who did not know the image or guessed incorrectly were corrected. The experimenter then picked up the |moon| card and repeated the process. When children had been introduced to both images the experimenter explained the game rules.

In the Standard Grass/Snow task the experimenter instructed the children 'When I say 'sun' you point to the moon card, and when I say 'moon' you point to the sun card'. Explanation of game rules for the Standard Grass/Snow task was accompanied by the experimenter using his finger to point to the correct target card to reinforce the response that should be provided by the child in reply to the experimenter's preceding verbal cue. In the Marker Grass/Snow task the experimenter instructed children ''When I put the wooden star on the |sun| card, you point to the |moon| card, and when I put the wooden star on the |moon| card, you point

to the |sun| card'. Verbal instruction was accompanied by the experimenter placing the marker on either the |sun| or |moon| cue card and pointing to the target card. In the Standard Reverse Sort task, children were told 'When you get a |sun| card, put it in the |moon| tray and when you get a |moon| card, put it in the |sun| tray.' In the Face-Down Reverse Sort task the experimenter verbally informed the child whether the face-down cue card was a |sun| or a |moon| card. Children then placed the face-down cue card into one of the two target trays according to the same rules.

To confirm children had understood SRC task instructions they were then asked if they remembered what to do. Children who remained unsure of the response that they should provide were again informed of the game rules. Once the experimenter had received confirmation that the child understood the rules of the game the experiment began with four practice trials. During practice trials children were provided with feedback; the experimenter corrected incorrect responses and confirmed correct responses. Children who failed to get at least three practice trials correct repeated the four practice trials. Children who did not successfully complete a second set of practice trials were omitted from further involvement in the test session. Children who did successfully complete the practice trials then completed 16 test trials. Each child then completed 16 test trials. No feedback was given during test trials.

Upon completion of the 16 test trials children were told that they had played a good game and were invited to pick a sticker of their choosing to keep. At the end of game one participants were invited to play another 'silly game' for which they would receive another sticker. At the end of game two children picked a sticker, were thanked by the experimenter

for taking part, and asked if they would like to play another set of games on another day. Children were then returned to the main playroom by the nursery school employee.

Table 4.3. The four SRC tasks used in Experiment 7.

Task	Rules
Standard Grass/Snow	Hear 'sun' point to |moon|, hear 'moon' point to |sun|
Marker Grass/Snow	See star on |sun| point to |moon|, see star on |moon| point to |sun|
Standard Reverse Sort	'See |sun| card place in |moon| card tray, see |moon| card place in |sun| card tray'
Face-Down Reverse Sort	'Hear |sun| place in |moon card| tray, hear |moon| place in |sun| card tray'

Figure 4.4. The two 'sun' and 'moon' images used in Experiment 7 SRC tasks.

4.3.3. Results

Total correct responses were summed for each SRC task and converted to form a percentage score (see Fig 4.5). Overall, performance was not similar across each of the four SRC tasks. Children were more accurate on the Marker Grass/Snow task than any other task.

Performance accuracy on the Standard Reverse Sort and Face-Down Reverse Sort task was similar. Accuracy on the Standard Grass/Snow task was worst of all SRC tasks.

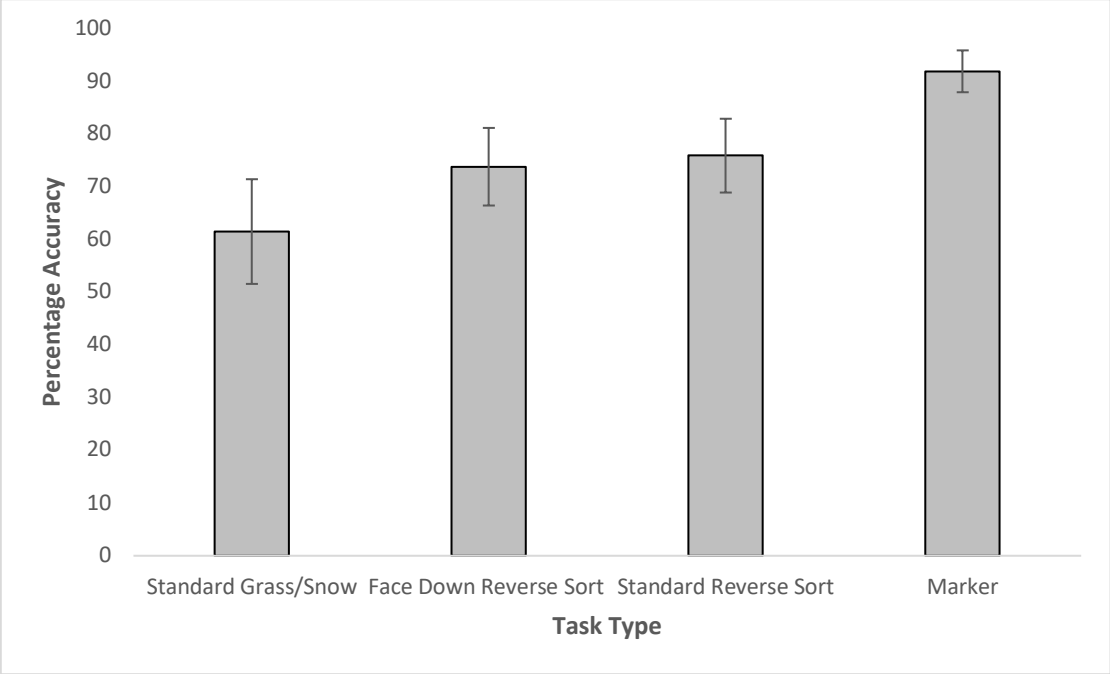


Figure 4.5. Performance accuracy of four SRC tasks including SEM error bars in Experiment 7.

First analysis of SRC data investigated for differences across each of the four SRC tasks. A within-participant one-way ANOVA used Standard Grass/Snow, Marker Grass/Snow, Standard Reverse Sort and Face-Down Reverse Sort tasks as independent variables. Mauchly's test indicated assumptions of sphericity had been violated, $\chi^2(5)=33.68, p<.001$ therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε =.61). Results showed there was a main effect for Task, $F(1.18,56.75)=12.55, p<.001$, and a small-medium effect size (η_P^2=.29). Accuracy was best on the Marker Grass/Snow task, followed by the Standard Reverse Sort and then the Face-Down Reverse Sort task. Accuracy was worst on the Standard Grass/Snow. Post hoc comparisons using a Bonferroni adjustment

showed significant differences between Face-Up task and Marker task (p= <.001); Face-Down task and Marker task (p=<.001); and Verbal task and Marker task (p=<.001).

Further analysis of the data investigated for differences between the Standard Reverse Sort and Face-Down Reverse Sort tasks. A Paired samples t-test showed there was no statistically significant difference between these two tasks $t(31)=-0.85, p=0.40$; 95% CI (3% - 7%). The effect size for this analysis (d = 0.15) was found to be small using Cohen's (1988) convention for a small effect (d =0.20). Correlational analysis showed a strong positive correlation between the two tasks $r(32)=0.84$, $p<.001$. Performance on each task is mirrored in performance on the other task.

I next investigated for effects of task order on SRC task accuracy. A one-way repeated measures ANOVA used the four tasks as independent variables. Mauchly's test indicated assumptions of sphericity had been violated, $\chi^2(5)=34.21, p<.001$ therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε =.56). There was no significant main effect of SRC task order $F(11.83,40.56)=.85, p=.597$, $\eta_P^2=.20$. No difference between the order in which SRC tasks are completed and children's performance on SRC tasks exists.

4.3.4. Discussion

Experiment 7 investigated Conceptualisation in SRC tasks. Under Conceptualisation the Reverse Sort task is easier than the Grass/Snow task because children conceptualise the former in an *IC-avoiding* way. I used four SRC tasks: two Grass/Snow (Standard Grass/Snow and Marker/Grass/Snow) and two Reverse Sort (Standard Reverse Sort and Face-Down

Reverse Sort). I hypothesised that in the Face-Down Reverse Sort task children would be unable to use an *IC-avoiding* conceptualisation (the 'make-a-pair' rule). I therefore predicted the Face-Down Reverse Sort task would be harder than the Standard Reverse Sort task.

As expected, Experiment 7 data showed performance on the Marker Grass/Snow task was good and performance on the Standard Grass/Snow task was poor. The Standard Reverse Sort and Face-Down Reverse Sort tasks showed intermediate performance. However, my hypothesis was not supported: statistical analysis showed performance on the Standard Reverse Sort task and the Face-Down Reverse Sort task was very similar. Thus, the Reverse Sort task is not easier than the Grass/Snow task because children conceptualise it in an *IC-avoiding* ('make-a-pair') way. Taken together, these results suggest inhibitory demands of the Reverse Sort task are lower than the Grass/Snow task, but still have some effect on performance.

4.4. Experiment 8

4.4.1 Introduction

In Experiment 6 I attempted to *increase* children's use of an IC-avoiding conceptualisation by using a Make-a-pair Reverse Sort task. If children used an *IC-avoiding* ('make-a-pair') conceptualisation when performing the Reverse Sort task, then performance would have been *improved* in the Make-a-pair Reverse Sort task. However, performance on the Standard Reverse Sort and Make-a-pair Reverse Sort tasks was similar, which suggests children were not using the 'make-a-pair' rule. In Experiment 7 I attempted to *decrease* children's use of an *IC-avoiding* conceptualisation by using a Face-Down Reverse Sort task. If children used an *IC-*

avoiding ('make-a-pair') conceptualisation when performing the Reverse Sort task, then their ability to do so would have been *impaired* in the Face-Down Reverse Sort task. However, performance was again similar on both Reverse Sort tasks, which suggests children were not using the 'make-a-pair' rule. Thus, Experiments 6 and 7 provide no evidence that children use an IC-avoiding conceptualisation in the Reverse Sort task. Nevertheless, both experiments do show that Reverse Sort task is easier than the Grass/Snow task. Visual observation of these tasks, however, suggests that children take more time to respond on the Reverse Sort task than they do on the Grass/Snow task. Thus, in Experiment 8 I investigate whether children respond slower in the Reverse Sort task than the Grass/Snow task, and if so, by how much.

In Chapter 1 I discussed three theories of delay and their alternative explanation of how it improves performance on some SRC tasks. Briefly, Active Computation (Diamond et al., 2002) suggests delay allows children time to actively compute a correct response; and Passive Dissipation (Simpson et al., 2012; Simpson & Riggs, 2007) suggests inappropriate responses are triggered faster than appropriate responses and the imposition of delay allows inappropriate prepotent responses to rise and fade before an appropriate response is chosen. Both, Active Computation and Passive Dissipation suggest delayed responding reduces inhibitory demands, and these accounts are not incompatible (Simpson & Carroll, in press). The Goal Reminder (Barker & Munakata, 2015) account, however, suggests delay itself doesn't really improve performance – nor do the manipulations used in other research reduce inhibitory demands (e.g. Diamond et al., 2002; Simpson et al., 2012; Simpson & Riggs, 2007) – instead it is the manipulations themselves during delay that make it easier for children to remember the rules.

Gerstadt et al. (1994) first observed the beneficial effects of a delay in responding on performance accuracy: children were more accurate on a Day-Night task when they took longer to respond. More recent findings seem to confirm the effect of delay and concomitant improvements on performance in IC dependent tasks, including: Day-Night (Ling, Wong & Diamond, 2016; Simpson et al., 2012; Montgomery and Fosco, 2012; Diamond, Kirkham & Amso, 2002); Go/Nogo (Simpson et al., 2012; Simpson & Riggs, 2007); and some Open tasks - Counterfactual Reasoning (Beck et al., 2011; Carroll, 2016) and Windows (Carroll, 2016).

In Experiment 8 I investigated whether children respond slower in the Reverse Sort task than the Grass/Snow task, and if so, by how much. Visual observation suggests card sorting delays responding in the Reverse Sort task, however, at present this is not known. I used two SRC tasks: a Standard Reverse Sort task and a Standard Grass/Snow task (see Table 4.3). Each task used one black and white image of a sun and one black and white image of a moon. The Standard Reverse Sort task used rules 'If I give you a |sun| card then put it with the |moon| card. If I give you a |moon| card then you put it with the |sun| card'. The Standard Grass/Snow task used rules 'If I say 'sun' then you point to the 'moon' card. If I say 'moon' then you point to the 'sun' card'. I hypothesised that the Standard Reverse Sort task is easier than the Standard Grass/Snow task because children respond more slowly when sorting cards, and delaying responding reduces a task's inhibitory demands. I predicted that children would respond slower on the Standard Reverse Sort task than the Standard Grass/Snow task. To enable analysis of reaction time, in Experiment 8 I video recorded children's responding.

4.4.2. Method

Participants

Study participants (N=24) consisted of pre-school children aged between forty-one months and fifty-four months (mean age = 49 months); 13 males. Children were recruited from nursery schools located in a mid-sized town in a semi-rural county in the East of England. All children spoke English as a first language and were predominately of white British ethnicity. None of the children had any special educational need or behavioural, emotional or social difficulties.

Design

A repeated-measures design was used. Stimulus type (Standard Grass/Snow task, Standard Reverse Sort task) was the independent variable. Participant accuracy and reaction time were the dependent variables.

Materials

Two black and white images were used in the Standard Grass/Snow task: a |sun| image and a |moon| image) (see Figure 4.4). Two laminated picture cards contained either a |sun| image or a |moon| image. Each picture card measured 14cm by 10cm. In the Standard Reverse Sort task two sorting trays measuring 15cm by 23cm were used. Each sorting tray was clearly labelled with a laminated |sun| or a |moon| picture card positioned in the centre-front of the tray. The Standard Reverse Sort task also used a further 8 laminated |sun| and 8 laminated |moon| image cards as cue cards.

Apparatus

A video camera and tripod were used to film the experiment. The footage was recorded on an SDHD memory card and then analysed on a computer using the software MPEG Streamclip.

Procedure

SRC tasks used the same *if-A-then-b/if-B-then-a* rule structure as Experiments 6 and 7. Children completed both SRC tasks. Each SRC task comprised four practice trials (order ABAB) and 16 test trials presented in a pseudorandom order (ABBABAABBABAABAB). Children completed two sessions of approximately 10 minutes in duration across two days. The sessions were not more than one week apart. SRC tasks were counterbalanced. Twelve participants completed the tasks in order: Standard Reverse Sort, Standard Grass/Snow; the remaining twelve participants completed the tasks in the opposite order: Standard Grass/Snow, Standard Reverse Sort.

Prior to beginning the SRC task children were collected from the main nursery room and invited to sit with the experimenter at a table in a quiet area of the nursery. All children were accompanied by a nursery employee who was seated close by but who was instructed not to help children during the testing. Children were then shown the SRC task materials and told the rules of the game.

Standard Grass/Snow task

The Standard Grass/Snow task was the same as the Standard Grass/Snow task used in Experiment 6 and 7. Children were instructed 'when I say 'sun' you point to the moon card, and when I say 'moon' you point to the sun card'. Explanation of game rules for the Standard

Grass/Snow task was accompanied by the experimenter using his finger to point to the target image to reinforce the response that should be provided by the child in reply to the experimenter's preceding verbal cue.

Standard Reverse Sort task

The Standard Reverse Sort task used rules 'see |sun| card - place in |moon| card tray, see |moon| card - place in |sun| card tray'. Explanation of game rules for the Standard Reverse Sort task was accompanied by the experimenter physically placing the cue cards in the target trays: the |sun| card was placed in the |moon| target tray and the |moon| card was placed in the |Sun| target tray to reinforce the response that should be provided by the child. Following confirmation by the child that they understood the rules of the SRC task they were taking part in, each experiment began with four practice trials (ABAB). During practice trials feedback was given for both correct and incorrect responses. Children then completed 16 test trials presented in pseudorandom order (AABAABABBABABBAB). No feedback was provided during test trials, however, the experimenter encouraged children to respond when necessary.

Measurement of reaction times were made to the nearest centisecond (one hundredth of a second). In the Grass/Snow task reaction time measurement began when the experimenter had finished saying the word 'sun' or 'moon', and ended when the child's hand touched the surface of the sun or moon target card. In the Reverse Sort task reaction time measurement began when the sun or moon cue card was made visible to the child, and ended when the surface of the cue card met the surface of the target tray.

4.4.3. Results

Accuracy

Total correct scores were summed for each SRC task and converted to form a percentage score (Figure 4.6). Overall, across each of the two tasks performance was not similar. Standard Grass/Snow and Standard Reverse Sort task accuracy showed performance was better in the latter than the former. Accuracy data from the two SRC tasks showed accuracy was better by 28.2% in the Standard Reverse Sort task than the Standard Grass/Snow task. A paired samples t-test indicated this difference was statistically significant t(23)= -3.62, p<.001; 95% CI (12% - 44%) The effect size for this analysis (d = 0.74) was between Cohen's (1988) convention for a medium effect size (0.5) and large effect size (d = .80).

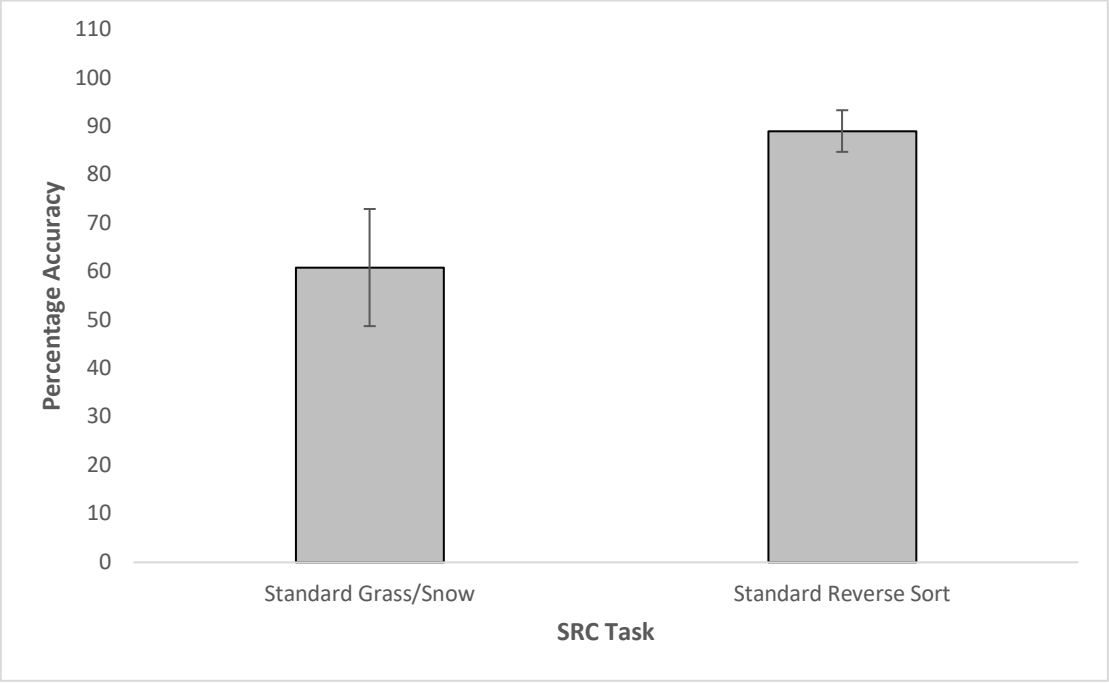


Figure 4.6. Performance accuracy of two SRC tasks including SEM error bars in Experiment 8.

Reaction Times

Reaction times were summed for each SRC task and converted to form a mean score (see Fig 4.7). Overall, across each of the SRC tasks reaction time was not similar. Mean reaction time data showed children were 1.84 seconds quicker to respond in the Standard Grass/Snow than the Standard Reverse Sort task. Paired t-test comparisons indicated this difference was statistically significant t(23) = -8.76, p<.001; 95% CI (9% - 14%). The effect size for this analysis (d = 1.78) was found to exceed Cohen's (1988) convention for a large effect (d = .80). Responses were provided quickest in the Standard Grass/Snow task and slowest on the Standard Reverse Sort task.

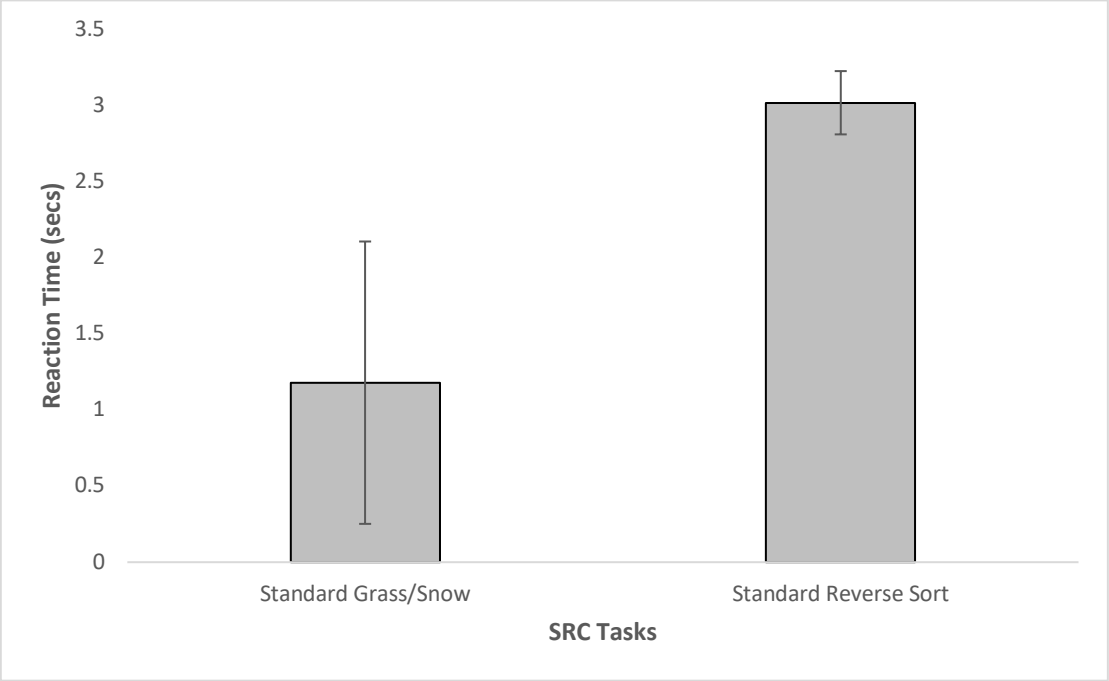


Figure 4.7. Mean Reaction Times of two SRC tasks including SEM error bars in Experiment 8.

4.4.4. Discussion

Experiment 8 investigated whether children responded more slowly in the Reverse Sort task than in the Grass/Snow task, and if so, by how much. I used two SRC tasks: one Standard

Grass/Snow and one Standard Reverse Sort. I hypothesised that the Standard Reverse Sort task is easier than the Standard Grass/Snow task because children respond more slowly on the Reverse Sort task, and delaying responding reduces inhibitory demands. I predicted slower responding on the Standard Reverse Sort task than the Standard Grass/Snow task.

Statistical analysis of Experiment 8 data showed the Standard Reverse Sort task was easier than the Standard Grass/Snow task: children were more accurate on the former than the latter. Moreover, children did respond more slowly on the Standard Reverse Sort task than on the Standard Grass/Snow task. In Standard Reverse Sort and Standard Grass Snow tasks children take about two seconds longer to respond when sorting cards than when pointing, so it may be that children are responding sufficiently slowly in the Standard Reverse Sort task for the delay to reduce inhibitory demands. As a result, Experiment 8 data supported my hypothesis that the Standard Reverse Sort task is easier than the Standard Grass/Snow task, and suggest that children respond more slowly when sorting cards and slowing responding reduces inhibitory demands.

4.5. General Discussion

The three experiments in Chapter 4 explored why the Reverse Sort task is easier than the Grass/Snow task. In the introduction to Chapter 4 I discussed two alternative explanations: (1) Conceptualisation, and (2) Delay. Under Conceptualisation, inhibitory demands can be circumvented by using an *IC-avoiding* conceptualisation; it is suggested Delay works because slowing down responding reduces a task's inhibitory demands.

In Experiment 6 I explored Conceptualisation in SRC tasks. I used two Grass/Snow tasks (Standard Grass/Snow and Marker Grass/Snow) and two Reverse Sort SRC tasks (Standard Reverse Sort and Make-a-pair Reverse Sort). I hypothesised the Reverse Sort task is easier than the Grass/Snow task because the Reverse Sort task can be conceptualised in an IC-avoiding 'make-a-pair' way. If all children use an *IC-avoiding* conceptualisation then performance on the Standard Reverse Sort task was expected to be as good as performance on the Marker task; in contrast, if only some children use the *IC-avoiding* conceptualisation then it was expected that telling them to use it on the Make-a-pair Reverse Sort task would have improved performance. However, the results of Experiment 6 did not provide evidence for my hypotheses: performance on the Standard Reverse Sort and Make-a-pair Reverse Sort tasks was similar.

In Experiment 7 I continued to investigate why the Reverse Sort task is easier than the Grass/Snow task. Experiment 6 had tried to *increase* children's use of the 'make-a-pair' rule; however, despite my best efforts to do so, only *some* – and not *all* - children may have adopted using the *IC-avoiding* conceptualisation ('make-a-pair'). Notwithstanding this failure, it may be that children do still use a 'make-a-pair' rule: it's just that children need to see the card in order to make a pair - when they cannot see the card, they cannot use an IC-avoiding 'make -a-pair' rule. Experiment 7 used two Grass/Snow tasks: Standard Grass/Snow and Marker Grass/Snow; and two Reverse Sort tasks: Standard Reverse Sort and Face-Down Reverse Sort. In the Face-Down Reverse Sort cue cards were presented facing downwards to make it less likely for children to use an *IC-avoiding* rule. I hypothesised the Reverse Sort task would be easier than the Grass/Snow task because children conceptualise the former task in an *IC-avoiding* 'make-a-pair' way. I predicted the Face-Down Reverse Sort task would be

harder than the Standard Reverse Sort condition. However, the results of Experiment 7 did not support my hypothesis: performance on the Standard Reverse Sort task was not better than the Face-Down Reverse Sort task.

Experiments 6 and 7 showed the Reverse Sort task is not easier than the Grass/Snow task because children use an IC-avoiding 'make-a-pair' conceptualisation. In Experiment 6, performance was not improved through *increasing* children's use of an IC-avoiding 'make-a-pair' rule; in Experiment 7 performance did not worsen through *decreasing* children's use of an IC-avoiding 'make-a-pair' rule. The question remains, then: why is the Reverse Sort task easier than the Grass/Snow task?

In Experiment 8 I investigated whether children respond slower in the Reverse Sort task than the Grass/Snow task, and if so, by how much. Visual observation of the Reverse Sort and Grass/Snow tasks suggest that children do take more time to respond on the former than on the latter. It is this slower responding that may support improved performance on the Reverse Sort task. Under a Delay account, the Reverse Sort task is easier than the Grass/Snow task. Experiment 8 used a Standard Grass/Snow task and a Standard Reverse Sort task. I hypothesised the Reverse Sort task is easier than the Grass/Snow task because children respond more slowly when card sorting, and slower responding reduces inhibitory demands. I predicted slower responding on the Standard Reverse Sort task than the Standard Grass/Snow task. The results of Experiment 8 supported my hypothesis: the Standard Reverse Sort task was easier than the Standard Grass/Snow task. It is important to note, however, Experiment 8 results do not imply a causal relationship; only that slower responding and better performance are observed to occur concurrently in the Reverse Sort task. To better

understand this relationship, Simpson et al., (in prep) conducted a similar experiment utilising fast and slow versions of the Reverse Sort and Grass/Snow task and provided further evidence for slower responding and better performance in the Reverse Sort task.

Taken together, the results of Experiments 6, 7 and 8 reported in this chapter show the Reverse Sort task is easier than the Grass/Snow task, and support the meta-analysis findings of Peterson et al. (2016). The results of Experiments 6 and 7, however, did not support a Conceptualisation account: the Reverse Sort task was not easier than the Grass/Snow task because children conceptualise it in an *IC-avoiding* ('make-a-pair') way. The tasks in which I attempted to increase (Experiment 6) or decrease (Experiment 7) the use of conceptualisation did not affect performance. In contrast, the results of Experiment 8 do show slower responding in the Reverse Sort task than the Grass/Snow task, and suggest that slower responding reduces its inhibitory demands. Active Computation (Diamond, Kirkham & Amso, 2002), Passive Dissipation (Simpson et al., 2012; Simpson & Riggs, 2007) and Goal Reminder (Barker & Munakata, 2015) theories of delay each propose it is intrinsically related to improved performance. Delay reduces a tasks' inhibitory demands. However, the research conducted in this chapter did not seek to test which theory of delay best accounts for improved performance in the Reverse Sort task, and so it cannot definitively provide an answer as to why delay improves performance.

In conclusion, Chapter 4 explored why the Reverse Sort task is easier than the Grass/Snow task. Two experiments investigated Conceptualisation; and one experiment investigated whether children respond more slowly in the Reverse Sort task than the Grass/Snow task. Taken together, the results show the Reverse Sort task is easier than the Grass/Snow task.

However, Experiment 6 and 7 did not support a Conceptualisation account of why this is so: the Reverse Sort task was not easier than the Grass/Snow task because children conceptualised it in an *IC-avoiding* way. In contrast, Experiment 8 does show children respond more slowly in the Reverse Sort task. Thus, it suggests that the Reverse Sort task is easier than the Grass/Snow task because children respond more slowly when sorting cards, and slower responding reduces inhibitory demands.

Chapter 5

General Discussion

5.1 Introduction

This thesis investigated the creation and avoidance of inhibitory demands in inhibitory tasks. Specifically, it addressed two important topics in young children's inhibitory control: (1) the automaticity of verbal imitation, and (2) why the Reverse Sort task is easier than the Grass/Snow task. This chapter will first summarise the empirical Chapters 2, 3 and 4. It will then discuss the application of their findings and future possible lines of investigation. I then go on to discuss the thesis' limitations, before ending the chapter with my concluding remarks.

5.2 Summary of Findings

Summary of Chapter 2

In Chapter 2 I investigated automaticity of verbal and manual imitation in SRC tasks. Simpson et al. (2013) first showed performance differences between verbal and manual imitation in SRC tasks: verbal imitation was easy to resist. They suggested a Complexity account of verbal imitation; it suggests words' complexity leads to a 'slow mapping' between speech perception and speech motor representations. Speech motor representations are therefore not activated, or are activated only very little, when perceiving speech. As a result, verbal imitation is not automatic, and is easy to resist.

The three experiments in Chapter 2 built upon the research of Simpson et al. (2013) and Simpson and Carroll (2014) to further investigate the role of complexity in young children's automaticity of verbal imitation. Experiment 1 investigated the Complexity account. It used three Verbal imitation tasks (Word – 'dog' / 'cup'; Syllable – 'woo' / 'boo'; and Vowel – 'ooo'

/ ‘eee’) and one Manual imitation task (Hand Game). Children took part in all four tasks across two testing sessions. The data were inconclusive: children were not more accurate on any of the Verbal conditions than on the Manual task. In this respect, Experiment 1 results were not consistent with the Complexity account of verbal imitation (Simpson et al., 2013; Simpson & Carroll, 2014): Syllable and Vowel conditions were not more difficult than the Word task. Further, previous findings that showed verbal imitation with words was easier to resist than manual imitation (Simpson et al., 2013; Simpson & Carroll, 2014) was not replicated.

Experiment 2a continued to investigate whether verbal imitation is only easier than manual imitation when the stimulus is more complex. On reflection, poor task performance in Experiment 1 may have been due to the children struggling to remember the task rules. Therefore, in Experiment 2a I scaffolded children’s rule learning. It used two Verbal imitation SRC tasks (Word – ‘dog’ / ‘cup’; Syllable – ‘woo’ / ‘boo’) and one Manual imitation task (Hand Game). Children took part in either the Word or Syllable task, and the Manual task. I predicted the Syllable condition would be as difficult as the Manual condition. The data showed the Word task was easier to resist than Manual task. However, Word and Syllable imitation performance was similar, so a Complexity account of verbal imitation (Simpson et al., 2013; Simpson & Carroll, 2014) was not supported.

In Experiment 2b I continued to investigate whether verbal imitation is only easier than manual imitation when the stimulus is more complex. It was possible that children’s were still struggling to remember task rules in Experiment 2a, despite my attempts to enhance rule learning. I addressed this concern by including a mandatory practice session in Experiment 2b. It used two Verbal imitation (Word – ‘dog’ / ‘cup’; Syllable – ‘woo’ / ‘boo’) and one Manual

imitation task (Hand Game). The relatively short test session used in Experiment 2a was also a cause for concern; I therefore increased the number of test trials to 20 per task. Children took part in all three SRC tasks. I again predicted the Syllable condition would be as difficult as the Manual condition. The result of Experiment 2b supported the Complexity hypothesis: word imitation was easier to resist than syllable imitation.

Taken together, the results of Experiments 2a and 2b in Chapter 2 suggest word imitation is less automatic than manual imitation: word imitation is easy to resist. Furthermore, the results of Experiment 2b are consistent with a Complexity account (Simpson et al., 2013; Simpson & Carroll, 2014): word complexity creates a 'slow mapping' between speech perception and speech motor production representations.

However, reflecting on the the stimuli and responses used in Experiments 2a and 2b suggests a confound may have impacted on children's performance: the syllables rhymed but the words did not. In this respect, syllables were similar but words were dissimilar. On this basis, I proposed an alternative account for children's ease with resisting verbal imitation: Dissimilarity. It suggests stimuli and responses that are less alike are easier to resist imitating. When stimuli and responses do not rhyme verbal imitation is easy to resist. It is this account I tested in Chapter 3.

Summary of Chapter 3

In Chapter 3 I focussed my investigation on verbal imitation. Its three experiments followed on from those in Chapter 2, and explored the effects of word complexity and stimulus-response dissimilarity on the need for IC when children resist verbal imitation. Experiment 3

investigated whether it is the complexity of words or the dissimilarity of stimuli and responses that makes verbal imitation easy for preschool children to resist. It used three Word imitation SRC tasks: Dissimilar-Complex (Hand / Water), Dissimilar-Simple (Shoe / Bee), and two Similar-Complex (Clown / Cloud and Sound / Round). It tested 3- and 4-year-olds' accuracy on each task. The results showed children were more accurate when stimuli were dissimilar rather than similar, regardless of complexity. The data were consistent with the Dissimilarity account of verbal imitation: verbal imitation was easier to resist when stimuli and responses were not phonologically similar.

In Experiment 4 I continued to investigate the effect complexity and dissimilarity on resisting verbal imitation. Children's learning of task rules is of paramount importance if IC is to be tested; preschool children may have problems learning the rules of Verbal imitation SRC task, however (Simpson et al., 2013). It may be that the results of Experiment 3 were impacted by preschooler's learning of the rules of the task. Therefore, to ensure that participants did know the task rules – and that IC was genuinely being tested - in Experiment 4 I tested the accuracy and reaction time of children aged 5- and 7-years-old.

Experiment 4 used four Word imitation SRC tasks, each consisting of two-Word pairs that differed in their complexity and dissimilarity. Under the Word Complexity hypothesis, it is harder to resist imitating simple words than complex words. It predicts Complex conditions will be harder than Simple conditions. Under the Word Dissimilarity hypothesis, it is harder to resist imitating when the stimulus and response are similar than when they are dissimilar. It predicts the Similar conditions would be harder than the Dissimilar conditions. Children completed each of the four tasks (Dissimilar-Complex – Bread / Milk or Drum / Tent;

Dissimilar-Simple – Egg / Day or Tea / Boy; Similar-Complex – Crab / Grab or Brick / Stick; and Similar-Simple – Bee / Key or Bye / Pie). The results showed a main effect for Complexity and a main effect for Similarity in accuracy; and main effects and an interaction for Complexity and Similarity in reaction time. Overall, findings were consistent with a Dissimilarity account: words that are less alike are easier to resist.

In Experiment 5 I investigated dissimilarity in verbal imitation. Experiment 4 reaction time results had shown a Similarity and Complexity interaction: performance on the Similar-Complex task was worse than on the Similar-Simple task. Reflecting on the stimuli and responses used in Experiment 4 I noticed a confound which may have accounted for this finding: the Similar-Complex condition used words with 3/4 of phonemes the same (75% similar), whereas the Similar-Simple condition used words with 1/2 phonemes the same (just 50% similar). So Similar-Complex words were actually more alike than Similar-Simple words. On this basis, I amended the Word stimuli used in Experiment 5. I used four Word imitation SRC tasks consisting of two-word pairs containing either zero, one, two or three phonemes that were the same. Children completed each of the four tasks. The results showed that verbal imitation was harder for children to resist the more similar the stimuli and responses. These result were consistent with a Dissimilarity account: verbal imitation was easier to resist when stimuli and responses were not phonologically similar.

Taken together, the results of the three experiments in Chapter 3 show verbal imitation can be easy in SRC tasks but only when the stimuli and responses are phonetically dissimilar. It may be that phonologically similar words interfere with one another. Alternatively, it may be that they trigger one another more. However, its exact nature is at yet unknown. Thus, they

provide evidence that children's ease with resisting verbal imitation is not due to word complexity, it is due to word dissimilarity.

Summary of Chapter 4

So far, the research in this thesis has focussed on investigating the creation of inhibitory demands in inhibitory tasks. In Chapter 4 I turned my attention to how preschool children may avoid inhibitory demands in inhibitory tasks. Specifically, I investigated why the Reverse Sort task is easier than the Grass/Snow task. A recent meta-analysis of almost two hundred studies measuring children's inhibitory control (Peterson et al., 2016) showed performance on a number of SRC tasks - Hand Game, Knock Tap and Grass/Snow – was similar, albeit with one exception: the Reverse Sort task. Strikingly, when sorting cards in the Reverse Sort task, preschool performed substantially better than they did on SRC tasks that involve resisting pointing, imitating and naming. Resolving the difference in performance on these two tasks would enable a greater understanding of the development of IC more generally.

One explanation for children's better performance on the Reverse Sort task is that they are using an *IC-avoiding* conceptualisation to circumvent its inhibitory demands. According to Simpson and Carroll (2018) conceptualisation is key to the establishment of inhibitory demands in SRC tasks. Importantly, this type of task requires IC when it is conceptualised using If/then rules (e.g. Simpson & Riggs, 2005a). It is possible children can conceptualise rules in an *IC-requiring* way, in which case the task consists of high inhibitory demands - or in an *IC-avoiding* way, in which case inhibitory demands are reduced. If the latter, then children do not need to employ their weak IC to be successful. In the Reverse Sort task, children may spontaneously adopt an *IC-avoiding* conceptualisation by choosing to 'make a pair' of cards;

however, they cannot employ this conceptualisation in the Grass/Snow task as they cannot see that they are making a pair.

An alternative explanation for young children's better performance relates to the greater amount of time it takes to respond in the Reverse Sort task than in the Grass/Snow task. Visual observation of the Reverse Sort task suggests card sorting delays responding. Research shows that delaying responding improves performance on a range of other developmental tasks (e.g. Beck et al., 2011; Carroll, 2016; Diamond, Kirkham & Amso, 2002; Ling et al., 2016; Montgomery & Fosco, 2012; Simpson et al., 2012; Simpson & Riggs, 2007), and it may be that this is what is also happening in the Reverse Sort task: the whole process of card sorting takes longer than pointing, and it is delaying responding that reduces its inhibitory demands.

The three experiments in Chapter 4 investigated why the Reverse Sort task is easier than the Grass/Snow task. Experiment 6 investigated Conceptualisation. It used four SRC tasks (Standard Grass/Snow, Marker Grass/Snow, Standard Reverse Sort and Make-a-pair Reverse Sort). If all children use an *IC-avoiding* conceptualisation then performance on the Standard Reverse Sort task would be as good as the Marker task – a task in which it is suggested all children use an *IC-avoiding* conceptualisation (Simpson & Carroll, 2018). However, if only some children use an *IC-avoiding* conceptualisation then telling them to use it on the Make-a-pair task (e.g. Horses like to eat apples. When I hand you an |apple|, give it to the |horse|, and when I hand you a |horse|, put it with the |apple|. Every time you put the horse and apple together) would improve performance. The results of Experiment 6 showed the Reverse Sort task was easier to resist than the Standard Grass/Snow task (replicating previous findings – e.g. Peterson et al., 2016). However, there was no difference in performance between the

Standard Reverse Sort task and Make-a-pair task. Thus, the data did not support my hypotheses that performance would improve when the Reverse Sort task was introduced in an *IC-avoiding* way.

Experiment 7 continued to investigate Conceptualisation in SRC tasks. Despite my best efforts to encourage children to use an *IC-avoiding* conceptualisation in Experiment 6 by introducing the task rules in a 'make-a-pair' way, it may be that only some children used the rule. Alternatively, it may be that children spontaneously conceptualised the two Reverse Sort tasks in an *IC-avoiding* ('make-a-pair') way because they could already *see* the cue cards, and thus always knew they needed to make a pair of cards on every trial. Being able to see the cue and response cards (Horses and apples) enables children to see that they are making a pair – and this encourages them to use the IC-avoiding conceptualisation. Children handling the response cards face down prevents them from being able to see that they are making a pair and discourages them from using this conceptualisation. If children are using an IC-avoiding conceptualisation in the Reverse Sort task then we expect fewer to do so in the face down condition, and so worse performance.

Experiment 7 used two versions of the Grass/Snow task: Standard Grass/Snow and Marker Grass/Snow; and two versions of the Reverse Sort task: Standard Reverse Sort and Face-Down Reverse Sort. The results showed the Reverse Sort tasks were easier to resist than the Standard Grass/Snow task. However, the Face-Down Reverse Sort task was not harder than the Standard Reverse Sort task. This suggests children were not spontaneously using an *IC-avoiding* ('make-a-pair') rule in the Standard Reverse Sort task; hhad they been doing so then performance would have been worse in the Face-Down Reverse Sort task, but it was not.

Thus, the results of Experiment 7 do not provide evidence for a Conceptualisation account – replicating previous findings (Experiment 6): the Reverse Sort task is not easier than the Grass/Snow task because children are using an *IC-avoiding* ('make-a-pair') rule.

In Experiment 8, I investigated whether children respond more slowly in the Reverse Sort task than the Grass/Snow task, and if so, by how much. Under a delay account, the Reverse Sort task is easier than the Grass/Snow task because sorting cards takes longer than pointing a finger, and slower responding when sorting cards reduces inhibitory demands. Visual observation of the Reverse Sort task suggests card sorting slows responding: children must wait for a card to be handed to them before they can then place it in the appropriate sorting tray. It is possible that because the whole process of card sorting takes longer than pointing a finger - particularly because children see the cue card and then have to wait while it is handed to them – that the Reverse Sort task is easier than the Grass/Snow task. I used two SRC tasks: Standard Reverse Sort and Standard Grass/Snow. The results of Experiment 8 showed the Reverse Sort task was easier than the Grass/Snow task, and replicated previous findings (e.g. Experiments 6 and 7; Peterson et al., 2016). Accuracy was better on the Reverse Sort task than the Grass/Snow task; Reaction Time was slower on the Reverse Sort task than the Grass/Snow SRC task. Thus, the results support my hypothesis, and are consistent with the proposal that children do respond more slowly on the Reverse Sort task, and it is delaying responding that reduces its inhibitory demands.

Taken together, the results of the three experiments in Chapter 4 show the Reverse Sort task is easier to resist than the Grass/Snow task. Experiments 6 and 7 do not support a Conceptualisation account: children do not spontaneously use an *IC-avoiding* ('make-a-pair')

conceptualisation of task rules. In contrast, Experiment 8 results do support the proposal that children respond more slowly in the Reverse Sort task, and delaying responding reduces its inhibitory demands.

5.3 Applications and Future Research

In the first part of this section I discuss Verbal imitation. Chapters 2 and 3 provide evidence for two important developmental questions concerning the creation of inhibitory demands in inhibitory tasks: (1) is automaticity of verbal and manual imitation different? – and (2) is children and adult's verbal imitation the same? In the second part of this section I discuss how the results obtained in Chapter 4 that show slower responding enables children to reduce inhibitory demands in inhibitory tasks allows a better understanding of theory and practice.

Is automaticity of verbal and manual imitation different?

Simpson et al. (2013) first suggested verbal imitation was easier to resist than manual imitation. They found children were more accurate on a Verbal imitation task than they were on either Action, Naming and Pointing tasks. As a consequence, they suggested verbal imitation is subject to less automatic activation than manual imitation. In a similar set of experiments, Simpson and Carroll (2014 – Experiment 1) echoed these findings: verbal imitation was easier to resist than manual imitation. However, the experimental results I obtained in Chapters 2 and 3, this thesis, suggest the results of Simpson et al. (2013) and Simpson and Carroll (2014) were caused by a confound. Importantly, Chapter 2 showed verbal and manual imitation *were* different – however, it is likely that this difference was observed only because the verbal stimuli and manual stimuli differed. In Simpson et al. (2013) the verbal stimuli were acoustically dissimilar (e.g. 'sun' and 'moon'), whereas the manual stimuli

were visually similar (e.g. finger, fist). In this respect, verbal and manual stimuli were not alike; as such, verbal imitation was generally easier to resist than manual imitation. It is possible that, given a greater level of similarity between verbal and manual stimuli (i.e. a verbal task uses similar stimuli, and a manual task uses similar stimuli), there may be no difference observed between verbal and manual imitation. Clearly, more research is needed to show that manual imitation is easy to resist if the stimuli and responses used are different. Researchers interested in better understanding manual imitation could utilise a range of manual gestures response sets, for example, 'raised arms' and 'pointed fingers' or 'hands on heads' and 'fists'.

Is children and adult's verbal imitation the same?

The focus of the experiments in Chapter 2 and 3 was on children's verbal imitation. However, previous research shows performance differences between children's and adult's verbal imitation. Simpson (2013) and Simpson and Carroll (2014) showed that, for young children, verbal imitation is easy to resist, whereas Fowler et al. (2003), for example, showed that, for adults, verbal imitation is difficult to resist. In other words, these data suggest that for children aged up to 11-years-old verbal imitation is not automatic, and for adults it is.

Reconciling the literature that shows children (Simpson et al., 2013; Simpson & Carroll, 2014), but not adults (Fowler et al. 2003), find it easy to resist verbal imitation has hitherto been problematic: why, indeed, should children (as old as 11 years) and adult's verbal imitation be different? However, the experiments in Chapter 2 and 3 offer a tangible explanation for the observed difference, and suggest young children's and adult's verbal imitation may not be different, after all. In these experiments I showed it is hard to resist verbal imitation when

stimuli rhyme, however, when stimuli do not rhyme verbal imitation is easy to resist. Importantly, a notable difference exists in young children's and adult's verbal imitation research: adult's use syllables (e.g. pa/ka - Fowler et al., 2003), but children use whole words (e.g. 'sun' and 'moon' - Simpson et al., 2013). Put another way, the syllables used in adult experiments rhyme, but the words used in child experiments do not. I suggest it is this that is the basis of observed differences in children's and adult's verbal imitation, rather than there being any real difference between children and adult's ease with resisting verbal imitation. Clearly, more research needs to be done to evidence this suggestion or otherwise. Therefore, future studies focussed on verbal imitation should pay particular attention to the stimuli used in young children's and adults' studies and ensure that they are the same.

The restriction of automatic imitation.

Automaticity is a useful cognitive tool. Underpinned by a tight linkage between perception and production representations, automaticity serves as a guide for action and in doing so arguably improves precision. In the manual domain, the positive implications of automaticity are clear: an observer's production of a manual gesture is supported and improved as a function of observing an actor's production of the same manual gesture. For example, a child may observe an adult using an artefact, say, a hammer, to drive a nail into a piece of wood, and she then imitates the hammering action to achieve the same goal.

In the verbal domain, the advantages of automaticity are also salient: children's learning of words is assisted by a cognitive system that has tight linkages between perception and production representations. It suggests that when children try to verbally imitate (i.e. say something similar), automatic activation of a motor representation assists their faithful

reproduction of that word (e.g. Simpson et al., 2013). For example, a child must say the word 'hospital' but incorrectly pronounces it as 'hostiple'. Automatic activation of a motor representation of the word 'hospital' – as a consequence of hearing the word being said by another – assists the child's faithful reproduction of that word. However, it would not always be useful or convenient to verbally imitate. The dissimilarity effect is – therefore - an important finding. It suggests that when children try to verbally produce something different to a heard word, automatic activation does not interfere. For example, a child wants to verbalise the word 'computer' but hears the word 'hospital'. The dissimilarity of the heard-word 'hospital' and the to-be-produced word 'computer' means that the child can easily verbally produce the word 'computer' despite activation of the motor representation for the word 'hospital'. Thus, the finding that word imitation is easy to resist when stimuli and responses are not alike suggests automatic activation of motor representations may benefit word learning, without interfering with speech production.

Delay

I now turn to Chapter 4, and the investigation of why the Reverse Sort task is easier than the Grass/Snow task. Importantly, the Reverse Sort task can now be added to a growing developmental literature that shows slowing responding on SRC tasks improves performance (Gerstadt et al., 1994; Ling et al., 2016; Simpson et al., 2012; Simpson & Riggs, 2007; Simpson et al., in prep). In doing so, to my knowledge, this research is the first to show a delay effect in the Reverse Sort task. Children seem to take about two seconds longer to respond when sorting cards on the Reverse Sort task than pointing on the Grass/Snow task – and two seconds is the length of delay used in delay manipulations in other tasks (e.g. Simpson & Riggs,

2007) – so it may be that children are responding sufficiently slowly in the Reverse Sort task for the delay to also improve performance, suggesting a reduction in inhibitory demands.

In Chapter 1 - and the introduction to Experiment 8 - I discussed three theories of delay and their alternative explanations for how it improves performance on some SRC tasks: Active Computation (Diamond et al., 2002), Passive Dissipation (e.g. Simpson & Riggs, 2007) and Goal Reminders (Barker & Munakata, 2015). Active Computation and Passive Dissipation suggest delay reduces inhibitory demands, and are not incompatible with one another. It may be that both processes are employed to reduce inhibitory demands (Simpson & Carroll, in press). The Goal Reminder account suggests manipulations during delay allow children the opportunity to consider the rules of the task: rule reminding, but *not* delayed responding, improves performance.

It is important to note that Experiment 8 cannot fully resolve this debate. It only explored whether children respond more slowly in the Reverse Sort task than the Grass/Snow task, and if so, by how much; Experiment 8 did not undertake to explore what was happening during the slowed period of responding. It could be argued, however, that in addition to slowing responding, the sorting process in the Standard Reverse Sort task reminds children of the task's rules; this is because handing children a cue card may have encouraged them to reflect on which rule to follow. As such, a Goal Reminder account (Barker & Munakata, 2015) may explain improved performance. However, the results of other experiments in Chapter 4 are inconsistent with this explanation: for example, in the Face-Down Reverse Sort task from Experiment 7, when handed a 'blank card' children were not encouraged to think about the task's rules – and performance on it was no better than the Standard Reverse Sort task. With

this comparison in mind, Active Computation (Diamond et al., 2002), and Passive Dissipation (e.g. Simpson & Riggs, 2007) accounts, but not Goal Reminder (Barker & Munakata, 2015), are consistent with the findings of Experiment 8.

Laboratory findings must be applicable to real-world situations. Therefore, the suggestion that slowing responding reduces inhibitory demands may have immediate and lasting benefits for young children in a variety of settings. Young children are often eager and quick to provide responses when questioned by adults, for example. However, their eagerness and rapidity to respond may often result in wrong answers being provided. Thus, knowledge of the benefits of slowed responding may enable a raft of interventions to be established that allow young children to overcome their weak IC in educational, cognitive and social domains. Therefore, future research must be oriented towards more fully understanding what cognitive processes children are utilising during slowed responding and which facilitate improved performance.

5.4 Limitations of the Study

In this thesis, I have provided evidence that verbal imitation associated with words is less automatic than manual imitation that involves simple manual gestures; and that slow responding associated with card sorting reduces a task's inhibitory demands. However, it is pertinent to identify and acknowledge the potential limitations inherent within the studies I carried out.

The first limitation I identify is that SRC tasks have both inhibitory and working memory demands. It may be that working memory demands vary between SRC tasks, and that this

can interfere with using these tasks to measure IC. Relatedly, it is essential that children can learn the rules of an SRC task if the task is to be used to measure IC – if children can't remember the rules, then IC will not be tested. It is important therefore to take care when teaching children the rules of an SRC task. Although young children can remember task rules, it is possible that not all children involved in Experiments 1, 2a and 2b, in particular, were able to learn the rules sufficiently well. At 3-years-old children's memory is far from well-developed. To enhance rule learning I considered carefully how to ameliorate the negative effects of children's age and memory by amending the methodology to ensure children were best placed to better understand task rules. Unfortunately, the brevity of the methods sections do not make clear where rule learning has been sufficiently attended to. Methodological limitations aside, however, it may be instead that children's inability to remember task rules was due to my limitations as a researcher. Testing young children is a difficult and demanding (but rewarding) undertaking. It requires a great deal of strategic thinking, manipulation, guile, humour and, above all, patience. It may be that the results of early experiments reflected a lack of understanding - on my part - to conduct experiments according to these states of mind; the communication of information and rules to children prior to testing may not have been as accurate, informative or child-friendly as it needed to be. Thus, poor performance observed in earlier studies may have been a consequence of this inexperience.

The second limitation I identify relates to the environments in which all of the testing sessions were carried out. As far as possible, I tried to ensure that children were tested in a quiet and peaceful location. However, this was not always achievable. On some occasions children were tested in a cordoned-off corner of a nursery room or corridor. These locations were often

busy, and noisy. For example, in Experiments 1, 2a and 2b, children may have been easily distracted by the constant noise and curiosity of their friends during testing sessions - and this commotion may have impacted on children's attentiveness and accuracy.

The third limitation I identify is establishing and maintaining access to preschool children. The experiments in this thesis relied heavily on the participation of a large number of children. However, gaining access to them was a time-consuming - and often, frustrating - process. It required that three 'levels' of access were granted, first by a school or nursery; second, by parents; and third, by the child themselves. Although access was denied at the outset on some occasions by schools and nurseries, I was – fortunately - still able to visit a healthy number of venues to test children. I achieved this through a dedicated and personable approach to communicating information. Moreover, when schools and nurseries, parents or children had questions relating to my research, I ensured that they were supplied with the additional information they needed to decide whether or not to provide support for my studies. I believe that adopting this style of 'open' approach to communication and research ultimately allowed me to maximise schools, parent's and children's participation.

5.5 Concluding Remarks

This thesis investigated the creation and avoidance of inhibitory demands in inhibitory tasks. In Chapter 2 I investigated verbal and manual imitation. I showed that verbal imitation was sometimes easier to resist than manual imitation, and, in doing so, I suggested that the results provided support for the Complexity hypothesis (Simpson et al., 2013; Simpson & Carroll, 2014). However, I also noticed that stimuli differed in their complexity *and* dissimilarity, and this may have impacted on the results. In Chapter 3 I investigated verbal imitation. I again

showed that verbal imitation was easy to resist. Furthermore, I provided evidence for the Dissimilarity hypothesis: when words are less alike they are easier to resist. In Chapter 4 I investigated two accounts for why the Reverse Sort task is easier than the Grass/Snow task: conceptualisation or delay. I showed that children do not conceptualise task rules in an *IC-avoiding* way. However, children do respond more slowly in the Reverse Sort task than the Grass/Snow task, and slower responding may reduce its inhibitory demands.

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Appendix 1.

Table 2. 1. Commonly used Manual imitation SRC tasks.

Task	Conflicting response	No. of Practice Trials	Practice Trial Success	No. of Test Trials	Feedback Given		Author
					Practice Trials	Test Trials	
Tapping Task	When E taps once, participant taps twice. When E taps twice, participant taps once.	**?**	**?**	**?**	**?**	**?**	Luria, Pribram & Homskaya, (1964 - Demo 11)
Hand Game	When E raises a fist participant raises a pointed finger, when E raises a pointed finger participant raises a fist.	**?**	**?**	**?**	**?**	**?**	Luria, Pribram & Homskaya (1964 - Demo 12)
Peg Tapping	When E taps the table with a dowel once, child taps with a dowel twice. When E taps the table with a dowel twice, child taps with a dowel once.	**?**	**?**	**?**	**?**	**?**	Passler, Isaac & Hynd (1985)
Peg Tapping	When E taps the table once, child taps twice. When E taps the table twice, child taps once.	**?**	**?**	**?**	?	?	Becker, Isaac & Hynd (1987)
Knock Tap	Knock on the table with ? when the examiner taps with ?. Tap with ? when the examiner knocks with ?.	**?**	**?**	**?**	**?**	**?**	Korkman (1988)
Hand Game	Show a fist when the examiner shows his/her finger, and to show a finger when the examiner shows his/her fist.	**?**	**?**	**?**	**?**	**?**	Korkman and Peltomaa (1991)

Knock Tap	Knock on the table when the examiner taps, and to tap when the examiner knocks.	**?**	**?**	**?**	**?**	**?**	Korkman, Liikanen & Fellman (1996)
Peg Tapping	When E taps the table with a dowel once, child taps with a dowel twice. When E taps the table with a dowel twice, child taps with a dowel once.	4 conflict	Must be correct on both rules at least once during practice. Any correct practice trials count as successful test trials	16 Trials 1 & 2 must be correct to continue test session	y	?	Diamond & Taylor, (1996)
Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist.	? imitation until gesture production confident ? conflict until gesture production confident	6 imitation 4 consecutive conflict	15 max or 6 consecutive correct responses	y	n	Hughes (1996)
Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist.	? imitation until gesture production confident ? conflict until gesture production confident	4 consecutive imitation 4 consecutive conflict	15 max or 6 consecutive correct responses	y	?	Hughes (1998a)

Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist.	imitation until gesture production confident	6 consecutive imitation	15 max or 6 consecutive correct responses	y	y	Hughes (1998b)
Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist.	imitation of gestures until competent	4 consecutive imitation 4 consecutive conflict	10	y	?	Hughes, Dunn & White (1998)
Knock Tap	Child knocks on the table when E taps on the table. Child taps on the table when E knocks on the table. Child taps with the side of fist when E knocks with the knuckles. Child knocks with knuckles when E taps with side of fist When E taps with palm, child does nothing	?	?	?	?	?	Klenberg, Korkman & Lahti-Nuutila (2001)
Hand Game	Fist / Flat hand on table	7 Imitation	n/a	7	First 2 trials. None for final 5 trials	First 2 trials. None for final 5 trials	Lang & Perner (2002)
Knock Tap	Child knocks on the table with knuckles when E taps on the table with palm of hand. Child taps on the table with palm of hand when E knocks on the table with knuckles	15 conflict	?	15	?	?	Perner, Kain & Barchfield (2002)

	Child taps with the side of fist when E knocks with the knuckles. Child knocks with knuckles when E taps with side of fist. When E taps with palm, child does nothing						
Hand Game Knock Tap	When E makes a fist, child points their finger. When E points their finger, child makes a fist. Child knocks on table with palm when E uses fist, child knocks on table with fist when E uses palm	? conflict ? conflict	? ?	? ?	? ?	? ?	Bohm, Smedler & Fossberg (2003)
Peg Tapping	When E taps the table with a wooden dowel once, child taps with a dowel twice. When E taps the table with a dowel twice, child taps with a dowel once.	3 conflict	Any correct practice trials counted as successful test trial.	16	y	?	Blair & Peters (2003)
Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist.	? imitation	?	?	?	?	Fahie & Symons (2003)
Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist.	6 imitation 4 conflict	? ?	15	?	?	Carlson, Mandell & Williams (2004)
Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist.	? imitation (until competent) 6 conflict	?	15	? y	? ?	Flynn, O'Malley and Wood (2004)
Knock Tap	Child knocks on table with knuckles when E uses flat palm. Child knocks on table with flat palm when E uses knuckles	**?**	?	15	?	?	Joseph & Tager-Flusberg (2004)

Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist.	? imitation ? – (brief) conflict	6	15	?	?	Carlson (2005)
Knock Tap	Child knocks on table with knuckles when E uses flat palm. Child knocks on table with flat palm when E uses knuckles	4	?	15	?	n	Joseph, McGrath & Tager-Flusberg (2005)
Peg Tapping	When E taps the table with a pencil once, child taps with a pencil twice. When E taps the table with a pencil twice, child taps with a pencil once.	? conflict	2 consecutive trials	14	?	?	Roberts & Powell (2005)
Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist.	? imitation	n/a	15 max or 6 consecutive correct responses	?	y	Roebers & Schneider (2005)
Hand Game	Flat hand / Fist	4 imitation	?	8	y	?	Chasiotis, Kiessling, Winter & Hofer (2006)
Hand Game	Flat hand / Fist	4 imitation	?	8	y	?	Chasiotis, Kiessling, Hofer & Campos (2006)
Knock Tap	When E knocks with ?, child taps with ?. When E taps with ?, child knocks with ? When E taps with side of fist, child knocks with knuckles. When E knocks with knuckles, child taps with side of fist. When E lays hand flat on table, child does nothing.	?	?	?	?	?	Cromer, Stevens, DePrince & Pears (2006)

Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist.	10 imitation	N/A	10	?	y	Pellicano, Maybery, Durkin & Maley (2006)
Tapping Task	Children were instructed to tap twice with a wooden dowel when the experimenter taps once, and once when the experimenter taps twice	?	?	16	?	?	Blair & Razza (2007)
Knock Tap	Child knocks on table with ? when E uses ?, child knocks on table with ? when E uses ? Knock on table with side of fist when E knocks on table with knuckles, knock on table with knuckles when E uses side of fist	?	?	?	?	?	Brocki, Nyberg, Thorell & Bohlin (2007)
Peg Tapping	When E taps the table with a dowel once, child taps with a dowel twice. When E taps the table with a dowel twice, child taps with a dowel once.	3 conflict	Children must pass practice trials. No pass success figure provided. Correct responses in practice count as successful test trials	16	y	?	Domotrovich, Cortes & Greenberg (2007)
Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist.	? imitation until competent 6 conflict	?	15	? y	? ?	Flynn (2007)

Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist.	? imitation	?	12	?	y	Hughes & Ensor (2007)
Knock Tap	?	?	?	?	?	?	Marlow, Hennessey, Bracewell & Wolke (2007)
Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist.	10 imitation	?	10	?	y	Pellicano (2007)
Tapping Task (Pencil Tapping)	?	?	?	?	?	?	Smith-Donald, Raver, Hayes & Richardson (2007)
Hand Game	Pointing one finger / Pointing two fingers	? imitation 4 conflict	?	15 max or 6 consecutive correct responses	y	?	Tardif, So & Kaciroti (2007)
Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist.	? imitation	?	12	?	y	Hughes & Ensor (2008)
Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist.	?	?	?	?	?	Karpinski, Scullin & Montgomery-Downs (2008)
Hand Game Peg Tapping	When E makes a fist, child points their finger. When E points their finger, child makes a fist. When E taps the table with a dowel once, child taps with a dowel twice. When E taps the table with a dowel twice, child taps with a dowel once.	6 imitation ?	? ?	14 16	? ?	? ?	Oh & Lewis (2008)
Knock Tap	?	?	?	?	?	?	Sinn, Bryan & Wilson (2008)

Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist.	? imitation ? conflict	? imitation 4 consecutive conflict	15 max or 6 consecutive correct responses	y	n	Bigham (2009)
Peg Tapping	When E taps the table with a pencil once, child taps with a pencil twice. When E taps the table with a pencil twice, child taps with a pencil once.	?	?	16	?	?	Kegel, van der Kooy-Hofland & Bus (2009)
Peg Tapping	When E taps the table with a dowel once, child taps with a dowel twice. When E taps the table with a dowel twice, child taps with a dowel once.	? Imitation 3 conflict	Any 2 correct practice trials count as first two successful test trials	16	y		Rhoades, Greenberg & Domitrovich (2009)
Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist.	6 imitation ? conflict	6 successful imitation 4 consecutive	15	?	?	Tregay, Gilmour & Charman (2009)
Knock Tap	?	10 imitation	?	10	?	?	Kolnik (2010)
Knock Tap	Child knocks with knuckles on table when the E taps with flat palm. Child taps with flat palm on table when E knocks with knuckles Child knocks on table when E uses the side of fist. Child uses side of fist when E knocks. Child does nothing when the examiner taps	? ?	? ?	15 15	? ?	? ?	Molfese, Molfese, Molfese, Rudasill, Armstrong & Starkey (2010)
Knock Tap	When E taps on the table with their fingers, child knocks on the board with their fist, and vice versa.	12 imitation	?	12 imitation 12 conflict	?	?	Nampiijja, Apule, Lule, Akurut, Muhangi, Elliott & Alcock (2010)

Tap Once, Tap Twice (Tapping Task)	When E knocks on table with fist, child taps on the table with fingers, and vice versa. When E makes a cutting motion in the air with fingers, child does nothing. When E taps once, child taps twice. When E taps twice, child taps once	12 imitation ?	?	12 imitation 12 conflict 12 conflict 12 imitation	?	?	
Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist.	10 Imitation	N/A	10	?	y	Pellicano (2010)
Knock Tap	Child knocks with knuckles on floor when E taps with flat palm. Child taps with flat palm on floor when E knocks with knuckles Alternative hand shape variants not identified	?	?	?	?	?	Prado, Hartini, Rahmawati, Ismayani, Hidayati, Hikmah, Muadz, Apriatni, Ullman, Shankar & Alcock (2010)
Knock Tap	Child knocks with knuckles on table when the E taps with flat palm. Child taps with flat palm on table when E knocks with knuckles Child knocks on table when E uses the side of fist. Child uses side of fist when E knocks. Child does nothing when the examiner taps).	? ?	? ?	15 15	? ?	? ?	Monette, Bigras & Guay (2011)

Hand Game	Pointing with one or two fingers	10 imitation	?	10	?	?	Olson, Tardif, Miller, Felt, Grabell, Kessler,Wang, Karasawa, & Hirabayashi (2011)
Hand Game	?	?	?	?	?	?	Rothlisberger, Neuenschwander, Cimeli, Michel & Roebers (2011)
Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist. Hand up / Hand down	6 conflict	n/a	16	y	n	Simpson & Riggs (2011)
Hand Game Peg Tapping	When E makes a fist, child points their finger. When E points their finger, child makes a fist. Tap once on a drum when E tapped twice, tap twice on a drum when E taps once	? ?	? ?	16 18	? ?	? ?	Ford, Driscoll, Shum & Macauley (2012)
Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist.	8 imitation 6 imitation	? ?	12	y	Rules repeated after each of first 4 test trials, then on 8th.	Hammond, Müller, Carpendale, Bibok & Lieberman-Finestone (2012)
Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist.	5 imitation	?	10	?	?	Lackner, Sabbagh, Hallinen, Liu & Holden (2012)

Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist.	8 imitation 6 conflict	? ?	12	? y	Rules repeated after first 4 trials and 8th trial	Müller, Lieberman-Finestone, Carpendale, Hammond & Bibok (2012)
Peg Tapping	When E taps the table with a dowel once, child taps with a dowel twice. When E taps the table with a dowel twice, child taps with a dowel once.	?	?	16	?	?	Brown, Ackerman, & Moore (2013)
Hand Game	Pointing with one or two fingers	10 imitation	?	10	?	?	Lane, Wellman, Olson, Miller, Wang & Tardif (2013)
Hand Game	?	?	?	16	?	?	Macauley & Ford (2013)
Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist.	10 Imitation	n/a	10	?	?	Pellicano (2013)
Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist. When E makes |thumbs-up|, child makes scissors. When E makes |hand-up|, child turns hand down	4 conflict ?	n/a ?	16 ?	? ?	N ?	Simpson, Cooper, Gilmeister & Riggs (2013)
Knock Tap	When E knocked on the table with a fist, child tapped with open palm. When E tapped with open palm, child knocked with fist.	8 imitation	?	24	?	?	Sulik, Eisenberg, Silva, Spinrad & Kupfer (2013)
Hand Game	Fist / Flat hand on table	? imitation 2 conflict	?	16	y	n	Watson & Bell (2013)

Knock Tap	When E knocks on table with ?, child knocks with ?. When E knocks on table with ?, child knocks with ?	? imitation	?	12	?	?	Allan & Lonigan (2014)
Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist.	? imitation	6 consecutive trials	15	?	y	Calderon, Jambaque, Bonnet & Angeard (2014)
Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist.	1 conflict	?	20	?	?	Earhart & Roberts (2014)
Hand Game Knock Tap	When E makes a fist, child points their finger. When E points their finger, child makes a fist. When E points a finger, child makes a fist. When E makes a fist, child does nothing. When E knocks on table with knuckles, child taps table with open palm. When E knocks on table with open palm, child taps table with knuckles.	? imitation ? imitation until dominant response established	? ?	25 (12 critical fist trials) 12	? y	? ?	Lerner & Lonigan (2014)
Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist.	4 conflict	?	16	y	n	Simpson & Carroll (2014)
Knock Tap	When E taps on table, child knocks. When E knocks on table, child taps When E knocks on table, child taps side of fist. When E taps side of fist, child knocks. Child inhibits any response when E taps.	?	?	30	?	?	Cheie, Veraksa, Zinchenko, Gorovaya & Visu-Petra (2014)

Peg Tapping	When E taps the table with a ? once, child taps with a ? twice. When E taps the table with a ? twice, child taps with a ? once.	2 conflict	?	16	?	?	Utendale, Nuselovici, Saint-Pierre, Hubert, Chochol & Hastings (2014)
Hand Game	Pointing with either one or two fingers.	10 imitation	?	10	?	?	Grabell, Olsen, Miller, Kessler, Felt, Kaciroti, Wang & Tardif (2015)
Knock Tap	Knock on the table with the knuckles or tapping on the table with an open palm	Until imitative response established	?	12	?	?	Allan, Allan, Lerner, Farrington & Lonigan (2015)
Knock Tap	Knock on the table with the knuckles or tapping on the table with an open palm	?	?	12	?	Y	Lonigan, Lerner, Goodrich, Farrington & Allan (2016)
Peg Tapping	When E taps the table with a dowel once, child taps with a dowel twice. When E taps the table with a dowel twice, child taps with a dowel once.	Until correct response	?	12	?	?	Korucu, Selcuk & Harma (2016)
Tapping Task	Children were instructed to enact the rule of tapping a peg once on the table when the experimenter tapped it twice and vice versa	?	?	16	?	?	Sturge-Apple, Davies, Cicchetti, Hentges & Coe (2016)
Tapping Task	Children were asked to tap a pencil once when the experimenter tapped twice and to tap twice when the experimenter tapped once	?	?	16	?	?	Abenavoli, Greenberg & Bierman (2017)
Tapping Task (Peg Tapping)	Children tap twice when the E tapped once and tap once when the E tapped twice 2nd Part	? ?	? ?	12 12	? ?	? ?	Ekerim & Selcuk (2017)

	Children were asked not to tap when the experimenter tapped three times						
Hand Game	Make a fist when E points their finger, point their finger when E makes a fist.	12 imitation	?	12	?	?	Emerson, Rowse & Sills (2017)
Tapping Task	Child is instructed to tap a wooden dowel twice when the researcher taps once, and to tap once when the researcher taps twice	?	?	16	?	?	Fay-Stammbach, Hawes & Meredith (2017)
Tapping Task	Children to tap once when the assessor taps twice and vice versa	?	?	?	?	?	Goble & Pianta (2017)
Tapping Task	Children were asked to tap twice if the evaluator tapped once and tap once if the evaluator tapped twice	?	?	?	?	?	Gomez & Yoshikawa (2017)
Tapping Task	The experimenter taps either once or twice a wooden dowel (22.5 cm long, 2.5 cm in diameter) on the desk and then hands it to the child, who has to do the opposite number of taps	?	?	?	?	?	Majerus & Barisnikov (2017)
Tapping Task (Pencil Tapping)	When an examiner tapped once children tap twice and when the examiner tapped twice, children tap once	?	?	16	?	?	Santillán & Khurana (2017)
Tapping Task (Peg Tapping)	Children were instructed to tap twice after the experimenter tapped once and to tap once after the experimenter tapped twice Part 2	?	Until showed understanding	12	?	?	Selcuk, Yavuz, Etel, Harma & Ruffman (2017)

	Children were asked not to tap after the experimenter tapped three times						
Tapping Task	When E tapped once with the dowel the child should tap twice, and when E tapped twice the child should tap once.	?	?	?	?	?	Simpson, Al Ruwaili, Jolley, Leonard, Geeraert & Riggs (2017)
Hand Game	Make a fist when E makes a flat hand, make a flat hand when E makes a fist.	6 imitation	5	15	?	?	Teepe, Molenaar, Oostdam, Fukkink & Verhoeven (2017)
Hand Game	?	?	?	?	?	?	Amani, Koruzhdeh & Taiyari (2018)
Tapping Task	?	?	?	?	?	?	Andrew, Attanasio, Fitzsimons, Grantham-McGregor, Meghir & Rubio-Codina (2018)
Tapping Task (Pencil Tapping)	Children were told to tap one time when the assessor tapped two times and to tap two times when the assessor tapped one time	?	?	?	?	?	Baker (2018)
Tapping Task	Children tap once with a wooden dowel when experimenter taps twice and (tap twice when experimenter taps once	No limit	When rules are understood	16	Y	N	Bowmer, Mason, Knight & Welch (2018)
Tapping Task	When an examiner tapped once with a wooden dowel, children were instructed to tap twice and when the examiner tapped twice, children were instructed to tap once	?	?	16	?	?	Choi, Jeon & Lippard (2018)
Tapping Task (Peg Tapping)	Tap twice when the E taps once and tap once when the E taps twice.	3	?	12	?	?	Doenyas, Yavuz & Selcuk (2018)

	2nd part of test Child does not tap after Experimenter taps	3	?	12	?	?	
Tapping Task	Child taps a wooden dowel twice when the researcher taps once, and taps once when the researcher taps twice	?	?	16	?	?	Fay-Stammbach & Hawes (2018)
Tapping Task	?	?	?	?	?	?	Hee, Xu & Krieg (2018)
Tapping Task	Child is asked to tap twice with a pencil when the tester taps once and vice versa	"brief"	?	16	?	?	Houwen, Kamphorst, van der Veer & Cantell (2018)
Hand Game	The child must point a finger when the experimenter made a fist and vice versa.	?	?	12	?	?	Gagne, Chang, Fang, Spann & Kwok (2018)
Tapping Task (Hammer Knocking Task)	Children were instructed to knock on a desk with a hammer twice when the experimenter knocked once and to knock on the desk once when the experimenter knocked twice	?	?	16	?	?	Ma, Chen, Xu, Lee & Heyman (2018)
Tapping Task	When E taps once, child taps twice. When E taps twice, child taps once	?	?	12	?	?	Nampijja, Kizindo, Apule, Lule, Muhangi, Titman, Elliott, Alcock & Lewis (2018)
Tapping Task (Pencil Tapping)	Child is instructed to tap with a pen once when the assessor taps it twice, and to tap twice when the assessor taps once	"Several"	?	16	?	?	Slot & von Suchodoletz (2018)
Knock Tap	Tap on the table with palm of hand when E knocks, knock on the table when E taps with palm	2	2	17	?	?	Snape, Krott & McCleery (2018)

Tapping Task (Pencil Tapping)	Tap twice with a pencil when E taps once, tap once when E taps twice.	?	?	10	?	?	Spiegel & Lonigan (2018)
Tapping Task (Pencil Tapping)	The child was asked to tap once when the assessor tapped twice, and tap twice when the assessor tapped once	?	?	?	?	?	Walczak & Chrzan-Dętkoś (2018)
Tapping Task (Peg Tapping)	Children tap their peg twice when E tapped his/hers once, and vice versa.	2	?	16	?	?	Zelazo, Forston, Masten & Carlson (2018)
Tapping Task (Pencil Tapping)	Children to tap once when the assessor taps twice and vice versa.	?	?	?	?	?	Goble, Sandilos & Pianta (2019)
Hand Game	Make a flat open hand when E makes fist, make a fist when E makes flat open hand	?	2	16	?	?	Blankenship, Slough, Calkins, Deater-Deckard, Kim-Spoon & Bell (2019)
Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist.	Imitation of gestures until competent 4 conflict	None	16	y	Confirmatory response	Lipscombe, 2019 – Experiment 1
Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist.	Imitation of gestures until competent 4 conflict	None	12	y	Confirmatory response	Lipscombe, 2019 – Experiment 2a
Hand Game	When E makes a fist, child points their finger. When E points their finger, child makes a fist.	imitation of gestures until competent 4 conflict	3 out of 4 practice trials correct. Two attempts at success at practice trials.	20	y	Confirmatory response	Lipscombe, 2019 – Experiment 2b

Appendix 2.

Table 4.1. Commonly used Card Sort and Grass/Snow SRC tasks.

Named Task (actual task)	Conflicting response	Pre-switch Trials	Post-switch Trials (incompatibility in parentheses)	No. of Practice Trials	No. of Test Trials	Test Trial Feedback	Author
Grass / Snow	Point to green card when E said "grass," point to white card when E said "snow"			2	16	?	Carlson and Moses (2001)
Card Sort (DCCS - cards)	Shape – rabbits/boats Colour – red / blue	5	5 (3)			N	Carlson and Moses (2001)
Card Sort (DCCS and Reversal Shift)	Shape – cars & suns / rabbits & butterflies Colours – red & yellow / blue & green	5	5	2		N	Lang & Perner (2002)
Grass / Snow	Point to green card when E said "grass," point to white card when E said "snow"			2 (or more)	16	?	Walker (2003)
Reverse Categorisation (DCCS – objects)	Big & little blocks / big & little buckets Mummy/ baby animals	?	?	6 6	12 12	N N	Carlson, Mandell and Williams (2004)
Grass / Snow	Point to green card when E said "grass," point to white card when E said "snow"			?	16	?	Carlson, Mandell and Williams (2004)

Grass / Snow (pointing Day Night task)	Point to sun card when E said “moon,” point to moon card when E said “sun”			4	16	N	Simpson, Riggs and Simon (2004)
Grass / Snow	?			?	?	?	Carroll (2005)
Grass / Snow	Point to green card when E said “grass,” point to white card when E said “snow”			Yes, unknown number	16	?	Carlson (2005)
Reverse Categorisation (DCCS – objects) Reverse Categorisation (DCCS – Cards)	Big & little blocks / big & little buckets Mummy/ baby animals Rabbits and boats / blue and red Stars / no stars	? 5	? 5	? ?	12 20	Rule reminder on every trial (24 months) or midway (3years) ?	Carlson (2005)
Grass / Snow	?			?	?	?	Carlson, Davis, & Leach (2005)
Grass / Snow	Point to green card when E said “grass,” point to white card when E said “snow”			2	16	?	Roebers & Schneider (2005)
Grass / Snow	Point to green colour chip when E said “grass,” point to white colour chip when E said “snow”			?	16	?	Sabbagh, Xu, Carlson, Moses, & Lee (2006)
Reverse Categorisation	?	?	?	?	?	?	Bibok (2007)
Grass / Snow	?			?	?	?	Kochanska, Aksan, Penney, & Doobay (2007)

Grass / Snow	Point to green card when E said “grass,” point to white card when E said “snow”			?	16	?	Lengua, Honorado, & Bush (2007)
Grass / Snow	Point to green card when E said “grass,” point to white card when E said “snow”			2	16	?	Albertson & Shore (2008)
Card Sort (DCCS)	Shape – rabbits/boats Colour – red / blue	5	5 (3)			N Rule repeated before each trial	Albertson & Shore (2008)
Reverse Categorisation (DCCS)	Shape – dogs & birds Colours – red & blue	5	5	2 demo	5	N Rule repeated after incorrect sort	Kloo, Perner, Kerschhuber, Dabernig, & Aichhorn (2008)
Grass / Snow (Snow / Grass)	?			?	?	?	Kochanska, Aksan, Prisco, & Adams (2008)
Grass / Snow	Point to the blue paper when E said ‘‘red’’ and to point to the red paper when E said ‘‘blue.’’			?	16	?	Oh & Lewis (2008)
Reverse Categorisation (DCCS)	Coloured objects	?	?	?	?	?	Bibok, Carpendale, & Müller (2009)
Grass / Snow	?			?	?	?	Ito (2009)
Grass / Snow (Snow / Grass)	?			?	?	?	Kochanska, Barry, Jimenez, Hollatz, &Woodard (2009)
Grass / Snow	?			?	?	?	Lackner (2009)

Grass / Snow	Point to a green card when E said ‘‘snow’’ and point to a white card when E said ‘‘grass.’’			?	16	?	Sabbagh, Bowman, Evraire, & Ito (2009)
Grass / Snow	*Same-set* Experimenter says ‘sun’ point to |moon| Experimenter says ‘moon’ point to |sun| *Different-set* Experimenter says ‘knife’ point to |fork| Experimenter says ‘table’ point to |chair| *Abstract* Experimenter says ‘car’ point to |abstract1| Experimenter says ‘boat’ point to |abstract2|			4	16	N	Simpson & Riggs (2009 – Experiments 2 and 3)
Grass / Snow	?			?	?	?	Allan (2010)
Reverse Categorisation (Sorting task – first phase only)	Baby animals & Mummy animals / baby box & mummy box (18months)						Bernier, Carlson & Whipple (2010)
Grass / Snow	Point to a green card when E said ‘‘snow’’ and point to a white card when E said ‘‘grass.’’			?	16	?	Lackner, Bowman, & Sabbagh (2010)
Grass / Snow	Point to a green card when E said ‘‘snow’’ and point to a			Until responded correctly	16	N	Sabbagh, Hopkins, Benson, & Randall Flanagan (2010)

	white card when E said ‘‘grass.’’						
Grass / Snow	Point to a green card when E said ‘‘snow’’ and point to a white card when E said ‘‘grass.’’		**Cool and hot tasks look up	2	16	?	Allan & Lonigan (2011)
Reverse Categorisation (DCCS)	Big & little blocks / big & little buckets	6	12	6 demo		Y	Baker, Gjersoe, Sibielska-Woch, Leslie, & Hood (2011)
Reverse Categorisation	Buckets / Teddy grahams & goldfish Mummy & Baby	6	6	1 demo		Rule reminder on every trial	Beck, Schaefer, Pang, & Carlson (2011)
Grass / Snow	Point to a green card when E said ‘‘snow’’ and point to a white card when E said ‘‘grass.’’			2	16	?	Drayton, Turley-Ames, & Guajardo (2011)
Card Sort (DCCS)	Rabbits / boats Red / blue	5	5(3)	1 demo			Drayton, Turley-Ames, & Guajardo (2011)
Grass / Snow	Point to a green card when E said ‘‘snow’’ and point to a white card when E said ‘‘grass.’’			4	10	?	Olson, Tardif, Miller, Felt, Grabell, Kessler,Wang, Karasawa, & Hirabayashi (2011)
Reverse Categorisation (DCCS)	Big & small buckets / Big & small cubes	6	12	? demo		Rule repeated in pre-switch trials Feedback in pre-switch	Poulin-Dubois, Blaye, Coutya, & Bialystok (2011)

						No feedback in test trials	
Grass / Snow (Rain / Snow game)	Lay down picture cards with snowflakes and raindrops: Pictures with raindrops have to be placed on the blue part of a chart and picture cards with snowflakes on the white part; the rule has to be reversed whenever the cards additionally depict a sun or a snowman.			?	?	?	Rothlisberger, Neuenschwander, Cimeli, Michel, & Roebers (2011)
Grass / Snow	Point to a green card when E said ‘‘snow’’ and point to a white card when E said ‘‘grass.’’			Up to a max of 10 Test trials began after 2 consecutive correct trials	16	N Prompts used if necessary	White, McDermott, Degnan, Henderson, & Fox (2011)
Reverse Categorisation (DCCS)	Stars & Trucks / blue and red	8	8				White, McDermott, Degnan, Henderson, & Fox (2011)
Reverse Categorisation (Sorting Task - first phase only)	Big & small buckets / Big & small blocks (18 & 24months)	?	?				Bellagamba, Laghi, Lonigro, & Pace (2012)
Grass / Snow	Point to a green card when E said ‘‘snow’’ and point to a white card when E said ‘‘grass.’’			2 demo 4 practice	16	Y – feedback if error committee and rule reminder	Carroll, Riggs, Apperly, Graham & Geoghegan (2012) – Experiment 1
Grass / Snow	Mummy & Me			2	10	?	Cuevas, Hubble, & Bell (2012)

Reverse Categorisation	?	?	?	?	?	?	Duvall (2012)
Reverse Categorisation (DCCS - objects)	Blue & red blocks / Blue and red buckets	4	12	1		N Sorting rule repeated after every trial	Hammond, Müller, Carpendale, Bibok, & Liebermann-Finestone (2012)
Grass / Snow (Snow / Grass)	?			?	10	?	Kim, Nordling, Yoon, Boldt, & Kochanska (2012)
Grass / Snow	Point to a green card when E said ‘‘snow’’ and point to a white card when E said ‘‘grass.’’			6	16	?	Lackner, Sabbagh, Hallinan, Liu, & Holden (2012)
Grass / Snow	Point to a green card when E said ‘‘snow’’ and point to a white card when E said ‘‘grass.’’			Up to 10 2 consecutive correct trials	16	?	Lahat, Degnan, White, McDermott, Henderson, Lejuez, & Fox (2012)
Reverse Categorisation (DCCS – objects)	Blue and red blocks / Blue and red buckets	4	12	1		N Sorting rule repeated after every trial	Müller, Liebermann-Finestone, Carpendale, Hammond, & Bibok (2012)
Grass / Snow	Point to a green card when E said ‘‘snow’’ and point to a white card when E said ‘‘grass.’’			3 (with feedback)	16	?	Nilsen & Graham (2012)
Grass / Snow	?	?	?	?	?	?	Sage (2012)
Grass / Snow	Point to a green card when E said ‘‘snow’’ and point to a			?	?	?	Zalewski, Lengua, Fisher, Trancik, Bush, & Meltzoff (2012)

	white card when E said ‘‘grass.’’						
Grass / Snow	Point to a green card when E said ‘‘snow’’ and point to a white card when E said ‘‘grass.’’			?	16	?	Allan, Lonigan, & Wilson (2013)
Reverse Categorisation (DCCS - objects)	Big & small blocks / Big & small buckets	6	12	6		N	Bellagamba, Laghi, Lonigro, Pace, & Longobardi (2013)
Grass / Snow	Point to a green card when E said ‘‘snow’’ and point to a white card when E said ‘‘grass.’’			Until 2 consecutive correct trials	16	N	Benson, Sabbagh, Carlson, & Zelazo (2013)
Grass / Snow	Mummy & Me Point to his or her own picture when E said ‘‘point to Mommy’’ and point to the picture of the mother when E said ‘‘point to [child’s name]”			2 (with feedback)	4	N	Caughy, Mills, Owen, & Hurst (2013)
Grass / Snow	?	?	?	?	?	?	Eisenberg, Edwards, Spinrad, Sallquist, Eggum, & Reiser (2013)
Reverse Categorisation (DCCS - objects)	Big & small blocks / Big & small buckets	?	12	?		?	Evans & Lee (2013)
Grass / Snow	Point to a green card when E said ‘‘snow’’ and point to a white card when E said ‘‘grass.’’			10 imitation	10	?	Lane, Wellman, Olson, Miller, Wang, & Tardif (2013)
Grass / Snow	?	?	?	?	16	?	Macaulay & Ford (2013)

Reverse Categorisation (DCCS – objects)	Big & small blocks / Big & small buckets	6	12	6		Restated rule before each each trial	Wyss (2013)
Grass / Snow (Hot Grass – Snow)	Point to a green card when E said ‘‘snow’’ and point to a white card when E said ‘‘grass.’’			?	10	10 prizes given before test trials. Ppts lose a prize for each incorrect answer	Allan & Lonigan (2014)
Grass / Snow	Point to a green card when E said ‘‘snow’’ and point to a white card when E said ‘‘grass.’’			2	16	?	Carlson, White & Davis-Unger (2014)
Grass / Snow	Touch the green field when E said ‘‘snow’’ and touch the white field when E said ‘‘grass.’’			4 (2 per word) (with feedback)	?	?	Fizke, Barthel, Peters, & Rakoczy (2014)
Reverse Categorisation (objects)	Big & small buckets / Big & small blocks	?	12	Yes (number unknown)	?	N	Gandolfi, Viterbori, Traverso, & Usai (2014)
Grass / Snow	Point to the sun picture when E said “moon”, and to the moon picture when E said “sun”			10 imitative	10	?	Grabell, Olsen, Miller, Kessler, Felt, Kaciroti, Wang & Tardif (2014)
Grass / Snow	Children place their hands on top of hand shapes glued to bottom of a board. Children point to the white card when the experimenter said “grass” and point to the green card			Until child understood rules	16	?	Nathanson, Aladé, Sharp, Rasmussen & Christy (2014)

	when the experimenter said "snow"						
Grass / Snow	Point to a green card when E said ''snow'' and point to a white card when E said ''grass.''			Until child shows correct responses	16	?	Nathanson & Fries (2014)
Grass / Snow	?			2	16	?	Sage & Baldwin (2014)
Grass / Snow	Point to a green card when E said ''snow'' and point to a white card when E said ''grass.''			'Several'	12	?	Van Reet (2014)
Grass / Snow	Point to a green card when E said ''snow'' and point to a white card when E said ''grass.''			2 correct practice trials	16	?	van Tilborg, Segers, van Balkom, & Verhoeven (2014)
Grass / Snow	Point to a green block when E said ''snow'' and point to a white block when E said ''grass.''			?	?	?	Allan, Allan, Lerner, Farrington & Lonigan (2015)
Reverse Categorisation (objects)	Yellow & blue boxes / yellow & blue cubes	?	?			Y	Blakey, Visser & Carroll (2015)
Reverse Categorisation (objects)	Big & small buckets / Big & small blocks	?	4				Di Norcia, Pecora, Bombi, Baumgartner, & Laghi (2015)
Grass / Snow	Point to a green card when E said ''snow'' and point to a white card when E said ''grass.''			2 (with feedback)	16	?	Johansson, Marciszko, Brocki & Bohlin (2015)
Reverse Categorisation (objects)	Yellow & red blocks / red and yellow buckets	6 ? ?	4 12(?)				Johansson, Marciszko, Brocki & Bohlin (2015)

	Cars into Horse buckets and Horses into Car buckets.						
Grass / Snow	Touch the green square when E said ‘‘snow’’ and touch the white square when E said ‘‘grass.’’			‘Several’	12	?	Petersen, Bates, & Staples (2015)
Grass / Snow	Point to the green chip when E said ‘‘snow’’ and point to the white chip when E said ‘‘grass.’’			?	16	?	Wade, Browne, Planmondon, Daniel & Jenkins (2015)
Grass / Snow	Move the magnet to the snow card when E says ‘mountain’ and to the mountain card when E says ‘snow’.			2	16	?	Fujisawa, Todo & Ando (2016)
Reverse Categorisation (DCCS - Card Sorting Task)	Rabbits and boats / red and blue	5	5				Fujisawa, Todo & Ando (2016)
Grass / Snow	Point to a green card when E said ‘‘snow’’ and point to a white card when E said ‘‘grass.’’			2	16	?	Hopkins, Smith, Skolnick Weisberg & Lillard (2016)
Grass / Snow (incorrectly labelled as Day-Night)	Point to the sun picture when E said “moon”, and to the moon picture when E said “sun”			?	12	?	Lonigan, Lerner, Goodrich, Farrington & Allan (2016)
Grass / Snow	Point to a green card when E said ‘‘snow’’ and point to a white card when E said ‘‘grass.’’			2	14	?	Mahy, Mohun, Müller & Moses (2016)
Grass/Snow	‘Grassy field’ and ‘Snowy field’ pictures used. Unclear how			2	16	N	Thibodeau, Gilpin, Brown & Meyer (2016)

	children identify correct picture card response.						
Reverse Categorisation (DCCS – Card Sort)	Squares and Stars / red and blue	5 cards correctly sorted (25 trials max)	5 cards correctly sorted (25 trials max)				Thibodeau, Gilpin, Brown & Meyer (2016)
Grass/Snow	Point to the white card when E said the word “snow”, point to the green card when E said “grass”			?	16	?	Yuile (2016)
Grass / Snow	When child hears the word ‘grass,’ press the ‘snow’ button, When child hears ‘snow,’ press the ‘grass’ button			1 demo Practice until correct	16	?	Anderson & Wagovich (2017)
Grass / Snow	Point to a green card when E said ‘‘snow’’ and point to a white card when E said ‘‘grass.’’			2	16	?	Atance, Metcalf & Thiessen (2017)
Grass / Snow	Point to a green card when E said ‘‘snow’’ and point to a white card when E said ‘‘grass.’’			2	14	?	Mahy, Bernstein, Gerrard & Atance (2017)
Grass/Snow	Point at the white card when the experimenter says “grass” and at the green card when the experimenter says “snow.”			2	16		Šimleša, Cepanec & Ljubešić (2017)
Grass / Snow	Point to the sun picture when E said “moon”, and to the moon picture when E said “sun”			4 (with feedback)	16	N	Simpson, Al Ruwaili, Jolley, Leonard, Geeraert, & Riggs (2017)

Grass / Snow	Point to a green card when E said ‘‘snow’’ and point to a white card when E said ‘‘grass.’’			4	17	Rule reminder after 8th trial	Snape & Krott (2017)
Grass/Snow	Point to a green card when E said ‘‘snow’’ and point to a white card when E said ‘‘grass.’’			?	?	?	Brown (2018)
Grass/Snow	Point to a white card when they heard the word ‘grass’ and a green card when they heard the word ‘snow’			?	?		Dawes, Leitão, Claessen & Kane (2018)
Reverse Categorisation (DCCS) Reverse Categorisation (Mummy & Baby)	Big & Little buckets / big & little objects Mother & Baby animal pictures / Mother & baby human picture buckets	6 6	12 12				Huber, Yeates, Meyer, Fleckhammer & Kaufman (2018)
Grass/Snow	Point to a white card when they heard the word ‘grass’ and a green card when they heard the word ‘snow’			3 2 correct responses	16	N	Palmquist, Kondrad & Norris (2018)
Reverse Categorisation (DCCS)	Rabbits and boats / blue and red	6	6				Palmquist, Kondrad & Norris (2018)
Grass / Snow	Point to a green card when E said ‘‘snow’’ and point to a white card when E said ‘‘grass.’’			2	14	?	Mahy, Mazachowsky & Pagobo (2018)
Grass / Snow (Verbal-Cue task)	1 rule –			4 (with feedback)	16	N	Simpson & Carroll (2018) – Experiment 1

	When I name one card, point at the other card. So when I say 'sun' you point to the other card. And when I say 'moon' you point to the other card 2-rule When I say 'sun' you point to the moon card. And when I say 'moon' you point to the sun card						
Grass/Snow	Point at the white piece of paper when experimenter said 'grass' and when the experimenter says "snow" they should point to the green piece of paper			2	17	?	Snape, Krott & McCleery (2018)
Grass/Snow	Point to the white block when the administrator says "grass" and to the green block when the administrator says "snow."			2	16	?	Spiegel & Lonigan (2018)
Grass/Snow	Point to the white card when the experimenter said "grass" and to point to the green card when the experimenter said "snow."			At least once point to the correct card following practice	16	N	Van Tilborg, Segers, van Balkom & Verhoeven (2018)
Grass/Snow	?			?	?	?	Fujisawa, Todo & Ando (2019)
Grass/Snow	Point to the white card when the experimenter said "grass"			'Several'	16	?	Morales, Miller, Troller-Renfree, White,

	and to point to the green card when the experimenter said "snow."			Up to 10 max			Degnan, Henderson & Fox (2019)
Grass/Snow	Point to the white square when the experimenter said the word "grass" and the green square when the experimenter said "snow."			Until correct on 1 Grass trial and 1 Snow trial.	16	N	Shamblaw, Benson, Harkness & Sabbagh (2019)
Reverse Categorisation (Sorting Task)	Sort yellow blocks into red buckets and red blocks into yellow buckets	6 to establish prepotent response	4				Liu, Zhou, Dong, S., Wang & Hao (2019)
Reverse Categorisation (objects)	Blue and red blocks / Blue and red buckets	4	12	1		N Sorting rule repeated after every trial	Yeung, Müller & Carpendale (2019)
Reverse Categorisation (Reverse Sort)	If/Then-Rule 'If you get a |horse| card then put it with the |apple| card, if you get a |apple| card then put it with the |horse| card' Combination-Rule 'Horses like to eat apples. When I hand you an |apple|, give it to the |horse|, and when I hand you a |horse| give it to the |apple|. Every time you put the horse and apple together'			4 (with feedback) 4 (with feedback)	16 16	N N	Lipscombe (2019) – Experiment 6

Grass / Snow (Verbal-Point) Grass / Snow (Marker Task)	Hear |horse| point to |apple| card, hear |apple| point to |horse| card. See star on |horse| card point to |apple| card, see star on |apple| card point to |horse| card.			4 (with feedback) 4 (with feedback)	16 16	N N	Lipscombe (2019) – Experiment 6
Reverse Categorisation (Reverse Sort)	Card Face-Up task See |sun| card place in |moon| card tray, see |moon| card place in |sun| card tray' Card Face-Down task Hear |sun| place in |moon card| tray, hear |moon| place in |sun| card tray			4 (with feedback) 4 (with feedback)	16 16	N N	Lipscombe (2019) – Experiment 7
Grass / Snow (Verbal-Point) Grass / Snow (Marker Task)	Hear |sun| point to moon card, hear |moon| point to sun card. See star on |sun| point to |moon|, see star on |moon| point to |sun|			4 (with feedback) 4 (with feedback)	16 16	N N	Lipscombe (2019) – Experiment 7
Reverse Categorisation (Reverse Sort)	If I give you a |sun| card then put it with the |moon| card. If I give you a |moon| card then you put it with the |sun| card			4 (with feedback)	16	N	Lipscombe (2019) – Experiment 8
Grass / Snow (Verbal-Point)	If I say 'sun' then you point to the 'moon' card. If I say 'moon' then you point to the 'sun' card.			4 (with feedback)	16	N	Lipscombe (2019) – Experiment 8