Preschoolers' Understanding of Symbol-Referent Relations:

The Contributions of Memory and Inhibitory Control-Conflict

by

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Abstract

This study investigated children's understanding of symbol-referent relations and contributions of memory and inhibitory control-conflict to this understanding. Three versions of a symbol task were used to investigate four-year-olds' ability to use symbols presented in maps to locate stickers hidden in a model room. Results indicate that children were most successful when symbol colour matched the referent, which was only marginally different from performance when symbols were arbitrary colours (i.e., colours not otherwise seen in the task). Performance was lowest when symbol colours conflicted with the referent (i.e., symbols were the colour of a different referent), suggesting that conflict poses additional demands when interpreting symbols. Furthermore, some memory measures were correlated with the arbitrary version and a measure of inhibitory control-conflict was associated with the conflict version. Finally, both memory and inhibitory control-conflict were found to be predictive of matching symbol task performance, above and beyond age and vocabulary.

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Table of Contents

Table of Contents Continued

List of Tables

List of Figures

List of Appendices

We use various types of representations in our daily lives, such as written words, numbers, photographs, maps, models, and musical notations. Consequently, we rely on the ability to interpret symbols in order to provide us with knowledge. Research to date investigating children's ability to use representations has not addressed children's understanding of different levels of resemblance in symbol-referent relation, or what skills facilitate the understanding of these levels. Therefore, the present study was conducted to investigate how the degree to which the symbols resemble their referents impacts children's ability to use representations, as well as the cognitive factors that influence children's success on symbol tasks.

DeLoache (1995) has defined a representation as something that stands for, or symbolizes, something else. For example, a green light means 'go'. As outlined by Eskritt and Lee (2002), representations are a method for communication as evident in spoken/written words and signs. Furthermore, representations can enhance cognition through metalinguistic awareness (Olson, 1994), logical reasoning (Goody & Watt, 1968), and analytic thought (Ong, 1982). For these reasons, an understanding of representations is an important aspect of cognitive development.

Although researchers have investigated children's ability to interpret representations in many ways, such as the ability to deal with models (DeLoache, 2000), as well as written language and numbers (Bialystok, 1992b), the focus of this thesis is to investigate children's ability to interpret representations that vary in the degree to which they resemble what they stand for. Maps are an interesting medium for the presentation of symbols because map symbols can represent their referents with varying degrees of resemblance. Symbols allow for representation through resemblance (e.g., a blue wavy line to indicate where a river is located), as well as with the use of arbitrary symbols (e.g., 'X' marks the location of treasure). Furthermore, if a legend is provided, representation can occur even when the symbols and referents are in conflict in some way (e.g., stickers of vegetables indicating where candy is located). The manipulation of the degree of similarity/conflict between the symbol and its referent can allow for a wider range of difficulty in symbol-understanding tasks.

I will begin with a brief introduction to various types of representations, and then review research examining children's ability to deal with symbols as representations. This background will provide information on the developmental period during which representational understanding emerges, as well as some of the specific cognitive factors (e.g., memory and inhibitory control-conflict) which may influence performance on tasks of a representational nature. Once I have established how children understand symbols, models, and pictures as representations, I will narrow in focus to discuss maps as a unique type of representational medium. Taken together, this review will highlight the need for research investigating how degrees of resemblance in the symbol-referent relation can influence children's understanding of physical representations. Following which, I will outline the hypotheses for the present study, describe the methodology that was used to carry out the investigation, describe the results and finally, I will discuss the significance and implications of the findings.

Types of Representations

According to Peirce's tripartite division of representations (Peirce, 1868), there are three broad classes of representations: icons, indices, and symbols. Iconic representations directly represent their referents by virtue of resemblance (e.g., a portrait). Second, representations can be indices that stand for the referents by virtue of something else (i.e., cause and effect). For example, smoke can serve as a representation of fire given the factual knowledge that smoke is an effect of that cause. The final category of representations, and the most relevant to this thesis, is symbols. Unlike the other two categories, symbols do not depend on resemblance or indexical connections, but instead represent objects through the way in which they are interpreted. Symbols can stand for of something else based on conventional meanings (i.e., their meanings are shared and agreed upon between members of a community; Bahtiyar & Sabbagh, 2010), or be newly created meanings (i.e., they are made to serve a goal as intended by their creator; Cohen, 1985).

Cohen (1985) outlined three criteria for effective symbols: (1) one-to-one mapping between a symbol and its referent in that each symbol has one and only one meaning (i.e., triangles should not represent both houses and picnic tables); (2) each meaning is represented through one and only one symbol (i.e., both triangles and squares should not be used to represent houses); and (3) the symbol-meaning relation remains consistent for both encoding and decoding (i.e., squares should not be encoded as the symbol for houses if triangles will then be decoded as the symbol for houses).

To examine children's understanding of these criteria, Cohen played musical tunes for five- to eight-year-olds and encouraged them to draw symbols of the sounds they heard so that they may be able to recreate the musical sequence. Results indicated a significant age difference between seven- and eight-year-olds for adherence to the one-to-one mapping rules. Furthermore, when comparing children's descriptions of encoding versus decoding of the same tune she found that younger children (five- and six-year-olds) allowed the meanings of the symbol to change. However, slightly older children (seven-year-olds) had understood the need for a consistency between encoding and decoding. This demonstrates that understanding and effectively using symbols according to the criteria outlined above is an ability which improves with development, particularly during this age range. Although this research is informative, it is limited to children's creation of symbols and their use of mapping rules. Several aspects of this task require additional skills, such as discriminating among musical tunes and remembering a variety of tunes and their symbols, and therefore place additional demands on the participants beyond understanding the symbol-referent relation. Therefore, other research which more closely narrows in on this relation will be discussed.

Bialystok (1992a) argued that symbolic thought is most evident when expressed in terms of notational systems and that symbols can be either external objects whose properties represent specific meanings (e.g., models), or internal representations that organize knowledge and determine meanings (e.g., ideas). Bialystok's research on children's representation of letters and numbers has suggested three stages of symbolic understanding: (1) ability to recite; (2) ability to recognize and produce in written form;

and (3) ability to understand the meaning/significance. Stages two and three extend beyond simply memorizing the sequence of letters and numbers because memorization alone is not sufficient for understanding the meanings of individual terms. Therefore, a higher-level understanding of the representations is needed to support the intended cognitive functions (Bialystok, 1992b). This suggests that simply knowing the symbol-referent relation is necessary but not sufficient for using that information to carry out an action. Therefore, an important area of research is investigating what factors affect children's ability to use knowledge of the symbol-referent relation.

Myers (2009) identified the usefulness of symbol-referent explanations as a factor which can facilitate children's understanding. To do so, an experimenter performed both iconic and arbitrary hand gestures, accompanied with explanations which either highlighted the correspondence between the gesture and the referent or contained irrelevant information. The results indicated that children were able to easily identify that an iconic symbol directly resembles the corresponding features of its referent and therefore children understood the connection between them. Although performance on arbitrary conditions was lower, it improved when relevant explanations of the symbol-referent link were provided. Myers concluded that symbols may be easier to understand when: (1) they resemble their referents; (2) children have knowledge of the referent; and (3) children are able to match the features of the symbol and the referent. A wide variety of other methods for presenting symbols to children has been studied. For example, Tomasello, Striano, and Rochat (1999) have found that the modality through which the symbol is presented has as affect on children's comprehension and production of it.

Although there are a variety of media through which symbols can be presented, the Tomasello et al. study compared children's ability to achieve symbolic understanding of gestures and objects. Results indicated that while children just younger than two years of age were able to comprehend gestures, objects were much more difficult. The difficulty experienced by children when using objects as symbols is particularly evident when the object being used has an established conventional use (e.g., using a drinking cup as a hat). Given these results, object symbols are an interesting way to study children's understanding of representations. Therefore, I will now review research on children's developing ability to understand objects such as models, pictures, and maps as representations.

Research on Children's Developing Symbolic Understanding

Children's emerging representational abilities have often been studied using scale models as representations to derive the information necessary to locate hidden objects in a larger-scale room (e.g., DeLoache & Burns, 1993; Troseth, Bloom Pickard, & DeLoache, 1997; DeLoache, 2000). To succeed on this type of task, children need to understand the way in which the smaller room stands for the larger room, and also understand that the smaller room can be used to inform them about the location of hidden objects in the larger room. DeLoache suggests that once an individual is able to detect and represent the relation between a symbol and its referent, *representational insight* is achieved. Furthermore, DeLoache argues that younger children are unable to accurately process the information provided by the scale model and retrieve the toy from the room because they have not yet achieved *dual representation*. According to the dual representation theory, children who successfully complete the task are able to see the model as *both* an object in-and-of itself and as a representation of something else.

In the standard scale model task, children were introduced to a model and oriented to the correspondence between the model (Little Snoopy's room) and a larger-scale room (Big Snoopy's room) through an item-to-item comparison (DeLoache, 2000). In each trial, children watched as an experimenter hid Little Snoopy in the model. The purpose of the task was to see if children were able to use the information presented by the model to retrieve Big Snoopy from his hiding place in the bigger room. For the most part, three-year-old children were successful in this task whereas two-and-a-half-year-old children consistently performed poorly, in spite of being able to remember where Little Snoopy was hidden in the model room. Further, because children as young as 14 months of age were able to follow instructions to retrieve a hidden object (Huttenlocher, 1974), DeLoache argues that the challenges children experience with the standard model task can be attributed to difficulties understanding the model as an information source rather than difficulties with following instructions and remembering locations.

Troseth, Bloom Pickard, and DeLoache (2007) examined an alternative to the representational insight hypothesis by examining whether children could achieve success on model tasks by simply detecting correspondences between a model and its referent (i.e., without having achieved representational insight). They compared children's performance on the standard model task to performance on a matching version which included additional information regarding the correspondence between items. The results indicated no difference between two-and-a-half-year-olds performance on a standard model task and a comparison task, suggesting that differences in performance are not merely due to a detection of correspondences but rather that a higher-level of representation, referred to as representational insight, is required for success.

DeLoache (2000) found support for the dual representation hypothesis by manipulating the salience of a model room. In Study 1 she placed the model room behind glass to make it untouchable, decreasing the physical salience (i.e., she increased its status as a representation). This manipulation increased their success on the task by making it easier for younger children (typically two-and-a-half-year-olds) to view the object as a representation of something else. In Study 2, DeLoache increased the physical salience of the model by allowing children to play with it as a toy prior to completing the task (i.e., she increased its status as an object in itself). In this condition, three-year-old children (who typically performed well on the standard task) demonstrated poorer performance when asked to retrieve Big Snoopy, suggesting that they experienced more difficulty when attempting to see the object as a representation. DeLoache's findings demonstrate that the physical salience of a symbol can affect children's ability to achieve dual representation and therefore influence performance on a retrieval task.

Interestingly, there is evidence that the challenges children face when using models as sources of information stem from difficulties understanding the representational nature of the task as opposed to an inability to use information from a small space to perform a task in a larger space. This conclusion was drawn by DeLoache, Miller, and Rosengren (1997) who monitored children's performance on a 'shrinking room' task. In this task, two-and-a-half-year-old children watched as a troll doll was hidden in a large room and were then convinced a machine 'shrank' the room into a scale model (the 'shrinking' took place behind closed doors). As predicted, children were significantly more successful retrieving the doll from the 'shrunken' room in this task than from the room in standard model task. The authors argued that success on this task may be attributed to the non-symbolic nature of the shrinking room because it is viewed by the children as one object changing in size, rather than as both an object and a representation. Therefore, dealing with dual representation was not necessary for success on the shrinking room task, so children were more successful at retrieving the hidden objects. As a whole, DeLoache's research has shown that young children are able to use scale models as representations of larger-scale rooms. To do so, however, both representational insight and dual representation must be accomplished.

Another aspect of the symbol-referent relation suggested to improve model task performance is an awareness of the model's intended purpose (Sharon, 2005). Sharon examined the intention of the model's creator as a factor which impacts children's performance on model task. Sharon claims that "what matters most is not what resemblances reside in the world between the proposed symbol and referent but what resides in the head of the person employing the symbol" (2005, p.164). Although this claim may be true for adults, Sharon clarified that understanding how the symbol and referent are linked can be confusing for young children and in some instances they may not be aware of any relation at all. Therefore, she investigated communication about the intention of the symbol as well as the symbol's intentional origins and intended function. Using two conditions, she examined the differences in performance between children who searched for a toy based on information provided by a model room (standard condition) and who searched for a toy based on information provided by a model room that was described as being made to help the child find the toy (intentional condition). The results indicated that two-and-a-half- to three-year-olds were better able to comprehend the symbolic relation between the scale model and the room in the intentional condition than in the standard condition. This suggests that knowledge of intention helps children understand symbols. Not only are there basic cognitive demands for interpreting symbols, but there are other components to consider such communicating the symbol's purpose to provide information about the symbol-referent relation.

Research on scale models, as discussed above, has identified aspects of representations that are influential in children's understanding of them and suggests that various factors may affect children's achievement of representational insight and dual representation. Therefore, the manipulation of these factors (such as discussing the creator's intention or increasing/decreasing model salience) appears to account for some differences in performance on scale model tasks. Although the model research has helped demonstrate how children understand models as representations, there is a shortage of research considering how variations of the symbol-referent relation can impact this understanding. Testing these variations is more practical in two-dimensional representational mediums (such as pictures and maps). For example, in the DeLoache standard model task, Little Snoopy in the model is used to indicate where Big Snoopy is hidden in the room. While Little Snoopy serves as a representation, it fits with Pierce's definition of an icon (directly resembling) as opposed to a symbol (relying on interpretation). Maps, on the other hand, can include many variations of symbols. While some research on two-dimensional representations has tapped into children's ability to use conflicting symbols, research investigating various levels of resemblance is still needed. A brief discussion of research on pictures/photographs will highlight not only the need for research more closely investigating children's understanding of the symbol-referent relation, but also the need for more research linking representational understanding with other aspects of cognition.

Children encounter challenges when they are required to use pictures as representations (e.g., Beilin & Pearlman, 1991; Zaitchik, 1990). This area of research involves two-dimensional representations of three-dimensional referents (unlike model research which involves smaller three-dimensional symbols representing larger ones). One of the most notable difficulties highlighted by the research on pictures has been children's tendency to assume that a symbol and its referent are matched in more than just appearance. For example, research has suggested that three-year-olds expect pictures of ice cream to be cold because they inappropriately apply the properties of the referent to the symbol as well (Beilin & Pearlman, 1991).

In addition, three- and four-year-old children may act as if pictures actually change to match a change in their referents (known as an 'updating error'). In a *false photograph* task (Zaitchik, 1990), children watched a Polaroid photograph of Ernie (a puppet) being taken while he was sitting up in a chair. The photograph was then placed face-down and Ernie was laid down for a nap. The children were asked questions about what Ernie was doing when the picture was taken, what he is doing now, and what he is doing in the photograph. Although most children were aware of where Ernie was when the photo was taken, they tended to mistakenly assume that in the photograph Ernie's actions matched what he was doing in the present moment. This is an indication that preschool children struggle with photographs that do not match the current state because they incorrectly assume the representation matches the referent at all times.

Sabbagh, Moses, and Shiverick (2006) conducted a follow-up study using the false photograph task to further examine children's tendency to overextend properties of a referent to the representation of that referent. They argued that children who perform poorly on the false photograph task are unable to inhibit responding with what they know to be true at the present time in favour of responding with what was true at the time the photograph was taken. This ability to inhibit an instinctive response (referred to as inhibitory control) may be an important cognitive ability in representational understanding.

Research reviewed thus far provides some insight into children's understanding of the symbol-referent relation. An in-depth investigation of how children interpret symbols varying in terms resemblance with their referents will provide further insight into how children use symbols as representations. However, these manipulations of symbol-referent relations is not possible in research using photographs in the same way that is available through research using maps as the representational medium. Therefore, I will now discuss research on children's understanding of maps and the symbols presented in them as representations.

Research on Maps

The term *map* is used to refer to a two-dimensional visual representation which stands for the physical features of a space (Liben & Yekel, 1996). They are drawings which contain representational correspondence (i.e., some item being used to represent another) and geometric correspondence (i.e., some spatial information about the actual space; Liben & Yekel, 1996). Liben and Downs (1989) argue that once an understanding of maps has been achieved, they become transparent—meaning that if an individual knows what they are looking at, they can look "through" the map to see what it represents.

The majority of research on children's use of maps has been carried out to investigate their ability to navigate space (see Uttal, 2000 for a review). Research in this area has demonstrated that preschoolers are able to identify depicted landmarks on aerial photographs (Blaut, McCleary, & Blaut, 1970), as well as learn the layout of a large playhouse by memorizing a map (Uttal & Wellman, 1989), and also use maps to find objects hidden in a field with common landmarks (Stea, Kerkman, Pinon, Middlebrook, & Rice, 2004). These results suggest that children are able to read and use maps, demonstrating their spatial abilities. A lesser investigated map-related skill is the way in which children understand the symbols as relating to external objects. Therefore, how children understand the symbol-referent relation will be the focus of the remainder of this thesis. Given that maps are the representational medium I will be using to investigate various symbol-referent relations, I will first review the limited research which focuses on maps as representations and how children interpret the symbols in maps. Then I will describe the cognitive abilities that may facilitate children's ability to understand symbols as representations of their referents, after which I will discuss my proposed study.

Liben and Downs (1989) explored the representational nature of maps through The Mapping Project at Penn State (MAPPS). The researchers argued that understanding maps is more than simply making judgements based on position, but rather encompasses skills such as language, reasoning, and visualization. Similar to the research described above on photographs, children also have the tendency to assume all properties are shared between a symbol and its referent when interpreting maps. Liben and Downs identified this pattern of behaviour as leading to errors when reading maps because children focus on specific graphical elements presented by the map as opposed to considering the symbolic context. Their work attempts to address the conceptual, functional, and formal properties of maps as well as children's ability to use them. Through interviews conducted with three- to six-year-old children and classroom activities carried out with five- to eight-year-old children, Liben and Downs observed how children understand correspondences between maps and their referents. They found that although children are often able to understand the map at the holistic level (i.e., the overall "this" stands for "that"), they still tend to have great difficulty seeing the map as a collection of symbols.

MAPPS is especially important because it focuses on the representational nature of maps by identifying what types of errors children tend to make on map tasks. However, this research does not address what abilities may play a role in committing such errors. Therefore, more recent research has attempted to further investigate performance on variations of map and symbol tasks and the factors which may impact performance.

Myers and Liben (2008) have provided information on how children use symbols presented in maps, and have highlighted aspects of children's map understanding which still need to be investigated. Five- to six-year-olds participated in a *map-intent* task which assessed children's attentiveness to the level of resemblance between symbols and referents, as well as their appreciation of the intentions of the map's creator (i.e., ability to realize that the maps were created *by* someone *for* someone to assist with a task). The researchers presented children with videos of actors who added dots to a map of a room for either a symbolic purpose (to indicate where something was hidden) or aesthetic purpose (to make the maps prettier). The dots which had aesthetic value matched the colour of the hidden objects (i.e., red dots matching the colour of hidden red, toy fire trucks), whereas the dots which had symbolic value were of an alternate colour (i.e., green dots showing where the red fire trucks were hidden). Although children were able to recall each creator's intentions, most were unable to use this knowledge to correctly choose which map would help them find the hidden objects. Instead, children based their responses on resemblance between the symbol and referent and choose the aesthetic maps. Therefore, it is clear that level of resemblance between a symbol and its referent is very salient to children in this age group.

The authors also examined children's abilities to use symbols which do not resemble their referents with their *use-a-map* task. The goal of this task was to determine whether children are able to use a legend to determine appropriate map symbols and then use the symbols in the task. In order to be successful on this task, children must understand the relation between a symbol and its referent despite the colours being in conflict with one another. Children were first oriented to the correspondences between a room and a map. They were informed that the map indicated the locations in the room where stickers were hidden. Children had the option of searching for either red fruit stickers or green vegetable stickers and they were made aware that the sticker locations in the room were indicated by dots of the alternate colour on the map (i.e., red fruit stickers were represented by green dots and green vegetable stickers were represented by red dots). They were then prompted to use the information provided by the map to place a cloth marker on the location of the sticker they were searching for (this was done to prevent them from actually looking for stickers until the end of the task). For each of the eight trials, the location of the cloth placement was recorded and the cloth was removed. On this task, a correct response involved using the legend to decide which dot represented the sticker of choice, overcoming the colour-conflict between the symbol and its referent, and then using the information provided by the map to mark the location of the sticker in the room.

Overall, children performed quite poorly on the task, correctly locating the stickers on less than 40% of the trials. The investigators implemented a more lenient scoring system to determine whether or not errors were due to the inability to overcome the colour conflict. To consider only the links between the map and the room (regardless of the colour of symbol), responses were scored as correct provided that they indicated the location of *a* sticker (not necessarily the sticker of choice). Using this scoring criterion, children's scores improved only slightly to 55%.

It is surprising that although these children seemed to understand the concept of the map standing for the room (as evidenced by following the experimenter's instructions and placing the cloth markers in the actual room), their scores were quite low. The authors argue that poor performance on this task is an indication of the challenges children face when identifying complex locations on maps. Myers and Liben use this information to speak to children's general understanding of maps, however it is also possible that the errors made are the result of the conflict built into the task.

Although the results do clearly indicate that children had difficulty with the task, it is unclear whether this difficulty was a result of children struggling with the relation between the map and its referent or whether the challenges children experienced arose from complications introduced with the conflicting symbols. For example, it is possible that children performed poorly because they were confused by the explanation of how the symbols were in conflict with the referents. Had the researchers included a condition in which the symbols matched the referents, it would have been possible to determine whether children actually understood the task prior to the inclusion of additional demands. Performance on this straight-forward version of the task would then serve as a baseline for interpreting children's performance on the conflicting symbolic relation between the map and the room.

Despite the poor performance on the use-a-map task, another task in this study yielded much higher performance levels—the *make-a-map* task. In this task, children used a map to record the locations of four blocks and four cars hidden by an experimenter. To mark the locations, they were able to choose from a variety of stickers which allowed them the option of eight identical stickers, eight completely different stickers, or subsets of stickers matched on either colour or pattern (however none of the stickers matched either type of the hidden objects on shape, colour, or pattern). Participants were told that the next child would be using the map and would be limited to searching in four locations for either the blocks or the cars. The experimenter hinted at developing a map key by asking participants if the next child would be able to differentiate between cars and blocks on the map.

Overall, performance was quite high with a mean of 7 out of 8 (*SD* = 1.70). Furthermore, 63% of participants consistently used two different types of stickers to differentiate between the two types of toys, and 73% of the total sample created a map key (the majority of which were determined to be effective). The authors suggest that the higher level of performance on this task may mean that children are aware of their own intentions and are able to convey them to others at an earlier point in development than being able understand the intentions of others. However, the authors acknowledge that due to the fixed order of the tasks, the better performance on this task could be due to an order effect as well.

As found in the results of the *use-a-map* task, resemblance between symbols and their referents is an influential factor for children when they are interpreting symbols in maps. This result led the researchers to conduct a second study to further examine the importance of iconicity between map symbols and their referents. To do so, they added a condition to the *map-intent* task in which the colour of the symbol neither matched nor conflicted with its referent (what the authors referred to as the 'neutral' condition). In this condition, children still needed to consider the intentions of the experimenter but did not need to overcome a colour-conflict. The results indicated that five- to eight-year-olds showed no preference for either colour of dot, with roughly half of the children choosing each colour. Older children however (nine- and ten-year-olds), selected the dot which was intended to represent the referent 100% of the time, suggesting that removing the conflict makes it easier for them to apply their knowledge of the map creator's intentions. Although the authors considered differences in performance between symbols which were either in conflict with or were arbitrarily related to their referents, they were not taking into account what it was about these levels of resemblance that accounted for differences in performance.

It appears as though the variations of the symbol-referent relation are altering the cognitive demands (as evidenced by children's performance). Myers and Liben's (2008) investigation of other skills was limited. They included a drawing-intent task (which assesses children's ability to identify the meaning of a drawing based on information provided by the creator) and a number conservation task (which assesses whether children are able to overcome perceptual conflict between number of chips in a row and the length of the row). The authors describe these tasks as measures of general cognitive ability when in fact they tap into specific skills. To more accurately consider the development of map understanding and its association with other cognitive abilities, a variety of skills should be considered. As mentioned above, a standard version of the task would allow for an examination of baseline performance on the map task. The administration of cognitive measures (such as measures of memory and inhibitory control) in conjunction with a standard version of the task, as well as variations of it, would allow for a more accurate investigation of how the different versions of the task alter the cognitive demands.

To address some of the limitations of the Myers and Liben (2008) use-a-map task, Astle, Vendetti, Jansman, Podjarny, and Kamawar (2009) examined four- and five-year-olds' performance on a modified version of this task. We used two versions of a symbol task: a "full-match" version and a "full-conflict" version. In both versions of the task, children were presented with a model room containing two types of hidden stickers as well as eight black and white outline sketches of the room (referred to as 'maps'). Each map had two symbols, one for each sticker type, which were located relatively distant from each other. The experimenter explained that the maps were made to help the participants find stickers. Children were then asked to choose their favourite sticker (orange tiger or green turtle), and both types of stickers were discussed equally throughout the instructions for the game.

In the full-match version, symbols on the maps perfectly matched the stickers in terms of both shape and colour (i.e., an orange tiger on the map indicated where an orange tiger sticker was hidden in the room). Therefore, in this version of the task, the experimenter explained that tigers on the map show where tiger stickers are hidden in the room and the turtles on the map show where the turtle stickers are hidden in the room. In full-conflict version, the symbols were in full conflict with the stickers on both shape and colour dimensions (i.e., a green turtle on the map indicated where an orange tiger sticker was hidden in the room). In this version, participants were told that the stickers got mixed up when making the maps, and so, an orange tiger on the map indicated where a green turtle sticker was hidden in the room and vice versa. For both versions of the task, legends highlighting the symbol-referent relation were placed on the table and children were asked check questions to ensure they understood the nature of the relation prior to being asked to point to the locations of the hidden stickers.

Astle et al. found that four- and five-year-old children performed near ceiling on the full-match version of the symbol task, indicating that they understood the task and were successful at finding the stickers when the symbols completely matched the referents. In contrast, in the full-conflict version, participants were unsuccessful at using the *correct* symbols and instead used the matching symbol as an indicator of the location. However, they still followed the correct procedure of using symbols to indicate the hiding places, suggesting that the difficulty children have with this task stems from their inability to overcome conflict in a symbol-referent relation. Although a battery of cognitive measures was included in this study (Forward Digit Span, Backward Digit Span, Counting and Labeling, Dimensional Change Card Sort, Black/White Stroop, Monkey/Tiger, Flexible Item Selection Task, and Peabody Picture Vocabulary Task), performance on these tasks did not correlate with performance on the symbol tasks (after controlling for age and vocabulary) given the floor and ceiling levels of symbol task performance. Therefore, more research is needed to investigate a lower level of conflict in the symbol-referent relation in order to narrow in on the demands preschool children must overcome when interpreting symbols. Furthermore, research examining a reduced degree of conflict will allow for more variability in the scores and make correlations with scores on cognitive measures apparent.

A consideration of map research, in conjunction with research on other symbols, highlights the need for research on varying degrees of resemblance in the symbol-referent relation. In addition, a more in-depth investigation of the role of cognitive skills in symbolic understanding is required. The research previously discussed on how children understand pictures as representations demonstrates their tendency to assume a symbol closely matches its referent. This helps explain why preschoolers may struggle with achieving dual representation, because they are unable to distinguish between the properties of the symbol and its referent. As mentioned above, Sabbagh and colleagues (2006) refer to inhibitory control to help explain children's performance on the false photograph task. Interestingly, DeLoache (2000) also proposes that achieving dual representation is linked with children's increasing ability to inhibit responding to a representation as the object itself. Although research on children's understanding of map symbols has alluded to performance on symbol tasks as being facilitated by the emergence of relevant cognitive skills, specific skills have not been measured. Therefore, I will now discuss executive function and how this relates to children's understanding of representations before moving on to the present study.

Executive Function

Executive function (EF) increases rapidly during the preschool years. It is linked to the prefrontal cortex (Stuss & Alexander, 2000) and includes skills required to carry out goal-directed behaviour. The development of EF skills has been the focus of a great deal of recent research due to its association with other aspects of development such as problem solving skills (e.g., Frye, Zelazo, & Palfai, 1995; Zelazo et al., 1996), future thinking (e.g., Atance & O'Neill, 2005), theory of mind development (e.g., Carlson & Moses, 2001; Carlson, Moses, & Breton, 2002), early literacy (e.g., Cain, Oakhill, & Bryant, 2000), and early numeracy skills (e.g., LeFevre, DeStefano, Coleman, & Shanahan, 2005; Geary, Bow-Thomas, & Yao, 1992) as well social understanding and academic achievement (e.g., Hughes, 1998). Furthermore, EF has been linked to several childhood disorders through low inhibitory control, including attention deficit/hyperactivity disorder, learning disabilities, and autism (e.g., Russell & Jarrold, 1999; Zelazo, Jacques, Burack, & Frye, 2002). EF skills show a dramatic increase in ability during the preschool years as children shift from having great difficulty to performing at ceiling level on age-appropriate tasks (e.g., Carlson, 2005; Frye et al., 1995; Jacques & Zelazo, 2005; Zelazo, Frye, & Rapus, 1996).

Research pertaining to EF contains differences in both methodology and organization of constructs, possibly stemming from the fact that measures of EF capture a variety of cognitive abilities (Brocki & Bohlin, 2004). In other words, while most cognitive tasks are designed to tap into a specific ability, they often tap into several others as well because skills relying on attentional control tend to overlap with each other. One method for addressing this limitation is to include a battery of tasks which combine to measure certain aspects of EF, as is done in this thesis.

Although there is not perfect consensus as to which skills should be labelled as EF skills, there is a fair bit of agreement among researchers that working memory, inhibitory control, and cognitive flexibility should be included (e.g., Bull & Scerif, 2001; Carlson et al., 2002; Diamond, 2006). Working memory (WM), refers to the capacity to temporarily hold and manipulate information (Baddeley, 1990). Inhibitory control involves the ability to overcome a prepotent (i.e., instinctive or built-up) response for a response determined to be more favourable according to circumstance (Frye et al., 1995). It is typically discussed in terms of delay inhibition (where the favourable response is to withhold a desired action until an appropriate time) or conflict inhibition (where the favourable response is to replace the desired action with a conflicting action). The final aspect of EF mentioned above is cognitive flexibility, which is the ability to shift from viewing something from one perspective to see it from another. It involves being able to consider more than one aspect of something and understand that while one categorization may be true, it may not necessarily be exclusive (Jacques & Zelazo, 2001). Although all components of EF are important skills to consider for investigations of cognitive development, the aspects most relevant for this thesis are working memory and inhibitory control-conflict (ICC). Therefore, I will now describe these skills in more detail, following which I will outline how research has linked these skills with representational understanding.

Working and short-term memory. One aspect of EF that will be considered in relation to understanding representations is WM. This skill is believed to be necessary to use maps as representations because although explicit instructions or legends may be present to provide some assistance, the relation between the symbol and its referent must be held in mind while transferring attention from one to the other. In addition to WM, short-term memory may also aid children on representational tasks. Like WM, short-term memory refers to a temporary storage of information. However, it is different in that it does not involve transfer of attention in order to update information being held in mind (Baddeley, 1990).

A prevalent WM model is one presented by Baddeley (1990). This model focuses on a central executive system, with what is referred to as two subsidiary slave systems: the phonological loop and the visuo-spatial sketchpad. According to Baddeley, the central executive operates as an attentional system (where actions are controlled through well-learned skills) and the supervisory activating system (which is capable of interrupting and modifying on-going behaviour). Both the phonological loop and visuo-spatial sketchpad are important aspects to consider in relation to representational understanding.

The phonological loop is comprised of verbal storage (holding speech-based information) and articulatory control (using inner speech to feed information back into storage; Baddeley, 1990). This verbal component of working memory likely plays a role in interpreting map symbols because individuals are required to remember the relation between the symbol and the referent, as well as the location of interest. For example, for a child to be successful in the standard model task, he or she must not only remember that Big Snoopy is hiding in the same place as Little Snoopy but also that Little Snoopy is hiding under the chair.

A common verbal WM task used with young children is the Counting and Labeling Task—a dual processing task that requires participants to count and label objects simultaneously (Gordon & Olson, 1998). Younger children are almost always able to both name items (e.g., "tree, gift, cow") and count them (e.g., "1, 2, 3"), without difficulty. However, when asked to name and count at the same time (e.g., "one is a tree, two is a gift, and three is a cow"), children younger than three-and-a-half years of age usually struggle and often respond by simply naming or counting again, or by naming while counting each toy as one (e.g. "one is tree, one is gift, and one is a cow"). Older children, typically five-year-olds, tend to be very successful on the task.

Given that the primary purpose of maps is to navigate space, the visuo-spatial sketchpad is an important aspect of WM to consider. Baddeley suggests that the visual component is concerned with processing what is being seen, as well as where it is in space. The spatial component, on the other hand, is more focused on geographic orientation and spatial planning (Baddeley, 1990). This is an important skill for children's performance on representational tasks because, for example, a child must not only remember that Little Snoopy is under the chair, but must make a note of the chair's position in the room to differentiate it from the other chairs.

A child-friendly version of the Corsi Blocks task is often used to measure spatial WM in preschool-aged children. In this task, children are presented with an array of lily pads and are instructed to follow the experimenter's lead as they pretend their fingers are frogs jumping from lily pad to lily pad. Typically, five-year-olds are able to successfully copy the experimenter's movements up to four lily pads in a row (Rasmussen & Bisanz, 2005).

The most common measure of short-term memory capacity is memory span (the longest sequence of items/digits a person can recall, in a prescribed order). This span is commonly measured in children with the Forward Digit Span task (Carlson et al., 2002). This task involves an experimenter listing strings of numbers and having participants repeat the numbers back in the same order they were heard. Strings increase in length by one number every two trials, until a child is unable to reproduce the numbers in the manner requested, at which point the task is terminated. Research demonstrates an age-related gain in memory capacity. For example, with the Forward Digit Span, kindergarten children are generally unable to recall a string of more than four digits, as opposed to a recall of approximately seven digits typically achieved by adults (DeMarie & Ferron, 2003).

Inhibitory control-conflict (ICC). As mentioned above, ICC involves the ability to stop oneself from doing what would usually be done in a particular situation and instead act in a way that conflicts with that response (called the 'prepotent' response). This skill is necessary for success on representational tasks which require overcoming an assumption that a symbol directly matches its referent in order to view a more contextually appropriate representation as being compatible with the referent. For example, in the Beilin and Pearlman study (1991) children must inhibit their knowledge of ice cream feeling cold to determine what properties apply to a photographic representation of it. Given that symbols are not exactly the same as their referents (according to Pierce's definition), it is clear that inhibitory control is necessary for symbolic understanding.

The most widely-known task assessing the ability to overcome a prepotent response with a conflicting one is the Stroop task. In this task, colour words are presented in the ink of another colour (i.e., 'red' may be printed in blue ink) and participants must ignore the printed word and report the colour of ink it is printed in (Stroop, 1935). However, this task is not suitable for children, so a variety of tasks have been designed to measure ICC in younger participants—the most widely used is the Dimensional Change Card Sort (DCCS). This task was developed by Frye et al. (1995) and is a simplified version of the Wisconsin Card Sorting Task (WCST; a measure of ICC in adults).

The DCCS is a robust measure of ICC and is highly correlated with other measures of EF (Wolfe & Bell, 2004). In this task, children are shown two target cards that vary in terms of their shape and colour (e.g., a blue boat and a red rabbit). The target cards are affixed to the tops of two small boxes. There are also test cards (to be sorted) that also vary along the same two dimensions, but in a different combination (e.g., red boats and blue rabbits). One of the dimensions is discussed with the participants as the dimension along which children are required to sort the cards and they are then presented with a series of cards to sort into the boxes by the relevant dimension. For example, if the target cards are a red rabbit and a blue boat, children might be asked to first play the colour game by putting all the red ones (even though they are boats) in the box with the red rabbit and putting all the blue ones (even though they are rabbits) in the box with the blue boat. They are reminded of this rule with each new card and then sort a series of cards on this first dimension. This sorting process is used to build a prepotent response (children's performance tends to be the same regardless of which dimension they begin with). Once this response pattern of sorting has been established, the experimenter informs the child that it is time to switch and sort the remaining cards according to the previously irrelevant dimension, which in this example is shape. This means that they are to put all the rabbits (even though they are blue) in the box with the red rabbit and all the boats (even though they are red) in the box with the blue boat. At this stage, children are required to inhibit the established prepotent response and replace it with the appropriate action according to the new post-switch rules.

As with other EF tasks, preschoolers undergo rapid changes in performance on the DCCS over a short period of time. Children around three years of age typically have great difficulty inhibiting the established prepotent response and therefore are unable to follow the post-switch rules despite the rules being repeated with each trial (i.e., they continue sorting by colour even after switching to the shape game). However, by age 5, children are typically able to inhibit the established response pattern and perform very well post-switch.

Some researchers were concerned that the shift in performance was due to a failure to recall the rules of the game. However, it does not appear that this is the case. Zelazo et al. (1996) demonstrated this by asking children where the cards belonged at the end of the task. The results indicated that even the three-year-olds remembered the rules of the game and understood where each card belonged, demonstrating that the difficulty they experienced with the task was indeed due to insufficient inhibitory control rather than memory demands.

ICC is also commonly assessed in children using a modified Stroop task called the Day/Night Stroop task (Gerdstadt, Hong, & Diamond, 1994). In the Day/Night Stroop task children are shown cards and asked to say the word "day" when they see a picture of the moon and say "night" when they see a picture of the sun. This task involves inhibiting one's natural response (stating the semantically congruent label) and providing the label identified by the experimenter as the correct choice (the semantically incongruent label). However, the task can be seen as slightly problematic as the prepotent response to seeing a picture of a sun or moon may be to say "sun" or "moon" rather than "day" or "night". This does not fit with the definition of ICC in that the correct response is not in direct conflict with the actual prepotent response. Therefore, a more straight-forward version of the task has been developed (Podjarny, Vendetti, Eisen, & Kamawar, 2008). The Black/White Stroop involves solid black and white cards rather than picture cards and requires that children respond with "white" or "black" when shown the alternative. The required responses, unlike with the Day/Night, are in direct conflict with the prepotent response for the stimuli. Performance on these Stroop tasks increases dramatically between the ages of 3 and 5 years (Gerstadt et al., 1994; Carlson & Moses, 2001).

Inhibitory Control-Conflict Linked With Other Representational Abilities

Research has demonstrated that ICC plays an important role in understanding representations. Sabbagh, Moses, and Shiverick (2006) have found ICC to be predictive of preschoolers' performance on false signs tasks (e.g., understanding that a sign pointing to someone's location is false after he/she has moved). In other words, in order to report the new location of the mover, children must be able to inhibit the information being provided by the sign. In contrast, the researchers did not find a relation between ICC and performance on false photographs scores. Therefore, the authors argue that ICC plays an important role when children are required to reason about events/symbols that are expected to represent reality. However, Podjarny, Vendetti, and Kamawar (2007) have found that even performances on false drawing tasks are positively related with measures of ICC if the participants create the drawings themselves. Although inconsistencies regarding the intention to represent reality are present, a link between ICC and understanding representations is a common thread in these studies.

Other research has also demonstrated the relation between ICC and representational understanding. Carlson, Davis, and Leach (2005) used the *Less is More* task, in children received a greater reward (e.g., five candies) if they pointed to a smaller one (e.g., two candies). When presented with actual candies, three-year-olds had difficulty inhibiting the response of pointing the candies they wanted in order to point to the smaller amount. However, Carlson et al. were able to demonstrate that three-year-olds' performance significantly improved when symbolic representations replaced candies in the task, even though the reward was the same. For example, when given symbolic representations such as a picture of a mouse for the small reward and a picture of an elephant for the large reward, children were more successful at pointing to the smaller reward in order to receive the larger one. Performance on this task was related to measures of ICC and WM, however only the correlation with ICC remained significant after controlling for age and vocabulary. This finding is a clear indication that ICC is necessary to overcome the instinctive response of pointing to what they would naturally assume is symbolic of the desired reward, and instead follow the experimenter's instructions to carry out the contextually appropriate response. This finding would appear to be relevant for any conflicting symbol-referent relation, however various levels of resemblance/conflict still require further investigation.

Research on written words as representations has further demonstrated the link between ICC and children's performance on tasks requiring representational understanding. One study examined children's understanding of word properties (prior to having learned how to read) with what is known as the *Moving Word* task (Bialystok & Martin, 2003). In this task, a card with the name of an object was placed beneath a picture of that object and the word on the card was read aloud to the participant (e.g., a picture of a bee and the written word 'bee'). Next, the picture card was removed and a new picture card (e.g., a picture of a frog) replaced it. Although the card with the written word remained the same, results indicated that children had the tendency to act as if the word on the card changed to match (i.e., children reported that the card with the word 'bee' on it now said 'frog'; Bialystok & Martin, 2003). This is evidence that children lack some understanding of the one-to-one mapping rules, in that they are allowing one symbol to represent more than one referent. Given the research previously discussed on children's tendency to overextend the properties of the referent to the symbol, this finding is consistent with the type of errors children tend to make on representational tasks.

Performance on the Moving Word task was also shown to be linked with ICC through a correlation with scores on the Day/Night Stroop task (Gerstadt et al., 1994). This is reasonable given that to be successful on the Moving Word task, children must inhibit the more salient response of saying the word shown in the picture and instead respond by saying the word known to be written on the card. This is evidence that ICC plays a role in understanding written words as a form of representations.

As evident in the discussion of different types of representations, preschoolers' understanding of representations increases while EF skills are developing. Furthermore, as discussed in the research above, ICC has been the skill most often linked with understanding representations. To ensure the relations with EF are not simply driven by differences in intelligence, language can be used as a proxy to control for development at a broader level.

Language

Language is an important skill to take into account when measuring other cognitive abilities given that communication with others, such as the experimenter, plays a critical role in cognitive tasks. A low level of performance on a task may be the result of not understanding the instructions rather than a deficiency in the skill being measured. For this reason, it is important to control for general receptive language when examining the relations among other skills to ensure that they are not simply the result of associations they each possess with level of language.

The Peabody Picture Vocabulary Test – Third Edition (PPVT-III; Dunn & Dunn, 1997) is a standardized measure of receptive vocabulary which involves presenting children with an array of pictures and asking them to point to the picture of the word spoken by the experimenter. This task is an index of verbal ability and is not only used to control for the effects of verbal ability on tasks administered in conjunction with it, but can also be used to monitor the correlations between language ability and other abilities being measured.

As discussed, ICC (controlling for vocabulary) plays a role in representational abilities which involved inhibiting assumptions about the symbol-referent relation. Therefore, research considering various levels of resemblance in the symbol-referent relation, and how these levels relate to ICC and memory, needs to be conducted. The following discussion of the present study aims to address this gap in the research.

The Present Study

Research to date has focused on children's performance on tasks involving various types of representations. Children's ability to use models, pictures, and maps as representations has shaped our knowledge of their understanding of how symbols work. Thus far, research on physical representations has investigated factors that impact children's success when interpreting representations, at what ages errors are being made, and how frequently these errors occur. However, as mentioned above, research has not uncovered what skills contribute to success in understanding different levels of resemblance in symbol-referent relations.

The first goal of the present study was to investigate how the degree to which the symbols resemble their referents impacts children's ability to use representations. This was done by varying the level of resemblance in the symbol-referent relation for different versions of a symbol task. Studying how the characteristics of the symbol-referent relation impacts a child's ability to use maps to find hidden objects allows for a better understanding how children become able to deal with symbols. Furthermore, performance on the variations of the task helps determine what level of resemblance is necessary for preschoolers to be successful on a symbol task.

The second goal of the present study was to examine cognitive factors that may influence children's success on symbols tasks. As described above, the particular cognitive factors of interest were memory and ICC. Some research on other types of representations (such as models and pictures) has demonstrated possible links with measures of ICC, showing that it is important to consider the role of this cognitive skill. Furthermore, memory is expected to play a role due to the requirement to remember the symbol-referent relation as well as the location of the sticker. Given the demands of the symbol task in the present study, it is reasonable to expect that cognitive skills facilitate an understanding of the symbol-referent relations.

To achieve these goals, three versions of a symbol task were used to assess children's ability to use map-based symbols to indicate the location of hidden stickers (the referents). In one version, the symbols are dots that match their referents in terms of colour. In the other two versions, the colour of the dots were either arbitrary or in conflict with the colour of their referents. Fitting with Pierce's (1868) definition, the dots are symbolic in that they represent their referents through the way in which they are interpreted by the symbol user. The tasks are used to tap into Bialystok's (1992a) third stage of symbolic understanding: understanding symbol meaning and significance.

Although all participants received the colour-match version (within subjects), participants received only the colour-arbitrary *or* colour-conflict version (between subjects). In addition, all participants were administered measures of memory, ICC, and receptive vocabulary. This research provides information about what aspects of representations cause difficulties for children who lack understanding, as well as what demands children are able to overcome.

Hypotheses. There were four hypotheses for the present study. The first hypothesis was that children would be more successful on the colour-match version than on the other two versions of the symbol task. The colour-match version is a straightforward task with fewer demands than the other versions, and given high scores on a similar task in a previous study (Astle et al., 2009), performance was expected to be near ceiling. However, children were expected to show poorer performance on the colour-arbitrary and colour-conflict versions.

The second hypothesis was that children's performance levels on the colour-arbitrary version would be higher than performance levels on the colour-conflict version. As seen in a previous study, conflict in the symbol-referent relation yields low performance scores (Astle et al., 2009). This pattern was expected because the additional cognitive demands in the colour-conflict version require that participants not only remember which symbols indicate which object has been hidden (memory component), but also require that participants inhibit their instinctive response regarding the symbol-referent relation (ICC component).

The third hypothesis was that performance on the colour-arbitrary version would be correlated with measures of short-term, verbal, and spatial memory. This was predicted because success on this task requires that participants not only remember the location of the sticker in the room based on what they learned from the map, but also keep track of which symbol represents which referent. Therefore, memory was expected to significantly correlate with performance on this version of the task, while controlling for age in months and PPVT score.

The final hypothesis was that performance on the conflict version of the symbol task would be correlated with scores of ICC because unique to this version of the task is conflict between the symbol and its referent. Hence, the conflict version requires children to overcome iconicity in favour of a more contextually appropriate response. Therefore, scores on measures of ICC were expected to be significantly correlated with scores on the conflict version of the task after controlling for age in months and PPVT score.

Method

Participants

Data was collected for a total of 79 children; however, 10 children were excluded from further analysis. Two children were excluded due to language barriers, six refused to complete at least one of the games, and two did not return for the second session. The remaining sample consisted of 69 children between 47 and 61 months of age: 33 children in the colour-arbitrary condition and 36 in the colour-conflict condition. The age range for the colour-arbitrary condition was 47 to 61 months with a mean age of 53.5 and a standard deviation of 4.0 (18 girls). The age range for the colour-conflict condition was also 47 to 61 months with a mean age of 53.5 and a standard deviation of 4.3 (24 girls).

The majority of the participants were recruited by contacting daycares in the Ottawa area and obtaining informed consent from both the daycare coordinator (see Appendix A), the parents of the children who participated (see Appendix B), and the children themselves (verbal consent). These children participated in the study while at the daycare by meeting with an experimenter in a separate room or quiet area. Participants were also recruited from a database of children who either participated in previous research (but not other symbol interpretation studies), or are siblings of previous participants, and once again parental consent was obtained (see Appendix C). Participants who were recruited through the database participated by coming to campus and joining an experimenter in the Children's Representational Development Lab at Carleton University. Each child completed the tasks with the experimenter while the parent watched the study via a television screen in the next room. All children who participated in the study provided verbal consent prior to beginning the tasks, and were able to discontinue testing at any time if they felt or appeared to be uncomfortable. Regardless of whether they completed the tasks, children were thanked and given stickers and/or a small gift as a token of appreciation.

Procedure

Participants completed the tasks in two sessions, each approximately 30 minutes in length, on an individual basis. Children who participated off campus completed the sessions roughly one week apart, in a quiet space made possible by the daycare/location.

The children who participated in the study on campus completed the two sessions in the same day, with a short break for a snack in between.

During the testing sessions, children completed the colour-match and one of the non-match versions of the symbol task (colour-arbitrary or colour-conflict). The colour-match task was counterbalanced across sessions, and the session which did not contain the colour-match task included one of the non-matching versions. Three measures of memory were included to assess each short-term memory (Forward Digit Span), verbal WM (Counting and Labeling), and spatial WM (Corsi Span). Furthermore, the two most commonly used measures of ICC, the DCCS and the Black/White Stroop, were included. Our modification of the NESPY-II Inhibition Task was also included because it yields more variability than the other measures and is more suitable for examining correlations (this task will be described in later methods). The order of the non-symbol tasks was fixed (see Table 1) to keep sessions consistent and investigate individual differences.

Table 1

Order of Tasks for Each Testing Session

Session	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6
1	Black/White Stroop	Symbol Task (match or non-match counterbalanced)	NEPSY-II Inhibition			
2	Forward Digit Span	Counting & Labeling	Symbol Task (different than session 1)	Corsi Span	DCCS	PPVT

Note. The non-matching symbol-task was the colour-arbitrary version for approximately ½ of the sample ($n = 33$) while the other participants received the colour-conflict version ($n = 36$).

Apparatus

Although the map task which inspired this study was conducted using maps of an actual room (Myers & Liben, 2008), I used a model room because it allows children to shift their attention between the map and the room in a simple glance and it is practical for testing in a variety of daycares. Therefore, two model rooms were each constructed from foam board. Each room consisted of a floor (49 cm long at the back; 52 cm long at the front; and 38 cm deep) and three walls (25 cm high; see Appendix D for photos). One room is a kitchen/dining room with yellow walls, containing hidden rubber duck and lady bug stickers. The other room is a bedroom/office painted green, with tiger and turtle stickers. The rooms each contained 10 to 12 pieces of children's wooden play furniture and two area rugs. In a previous study (Astle et al., 2009), sticker type was counterbalanced across rooms but was found to have no effect; therefore, stickers were fixed to rooms in this task. Although children were attempting to find eight stickers in each task, the rooms each allowed for more than 20 possible hiding places to leave room for error in the event that the child is simply guessing various locations. The rooms were counterbalanced across sessions and task versions.

To create the maps, photographs of each room were taken from the point of view of a child sitting in front of the model. The photographs were converted to line drawings using computer software and then traced by hand (see Appendix E). All maps were on white paper with black lines and contained colour symbols (coloured dots) indicating where objects were hidden in the corresponding room.

Tasks

The protocols which were used to administer the following tasks can be found in Appendices F through O.

Symbol task. As previously mentioned, the main task used in the present study (see Appendices F through H) was developed based on a task used by Myers and Liben (2008). The task begins by ensuring that children are first able to identify the colours (orange, green, red, yellow, blue, pink, and brown) and the items (tiger, turtle, lady bug, and rubber duck) that are used in the task. They were then shown the model room and a corresponding map. Participants were oriented to the map by discussing the links between the map and the model room without naming the locations (i.e., "See this in the map? Here it is in the room"). Locations were not explicitly stated out of concern that labeling the exact location would allow children to pinpoint the corresponding area in the room without actually attending to where the experimenter was pointing to in the map. The map was aligned with the front of the room to allow children to easily spot the relation between the map and the room. Research has demonstrated that this alignment allows for increased success, relative to most other orientations (Bluestein & Acredolo; 1979).

Participants received the colour-match version of the symbol task and either the colour-conflict or colour-arbitrary version, counterbalanced between sessions. Colour was used as the discriminating factor between stimuli, as is frequently seen in child development research (e.g., variations of the Stroop task and DCCS). Research has demonstrated that when presented with stimuli to be matched on the basis of colour or shape, preschool-aged children tend to match on the basis of colour (while older children are more likely to attend to shape; Corah, 1964). Reese (1975) suggests that younger children's selective attention to colour may due to colour applying to an item as a whole (and therefore can be determined in a simple glance), whereas shape requires more focus on the perimeter. Given younger children's attentiveness to colour, items with canonical colours (tigers, turtles, rubber ducks, and lady bugs) were chosen as the referents for the present study, and their corresponding colours (orange, green, yellow, and red, respectively) were the symbolic representations in the colour-match version.

In all versions of the task, children were told that the experimenter had hidden two kinds of stickers in the room. First, they were asked to select the kind that they like the most and would like to find in the following game. In the colour-match version, children were informed that coloured dots on the maps match the colour of hidden stickers. The experimenter also explained that the coloured dots which match the colour of the alternate sticker show where those stickers are hidden in the room. For example, if a child chose to look for tiger stickers, the experimenter explained that the orange dots on the map show where the orange tiger stickers are hidden in the room and the green dots on the map show where the green turtle stickers are hidden in the room. To help children remember, they were presented with a legend which clearly displayed the relation between the coloured dots and the corresponding hidden stickers (see Appendix I). Before searching for the stickers, children were asked a check question to determine whether they were aware of which coloured dot indicated the location of the desired type of sticker (i.e., "Are you going to look for the tiger stickers where the orange dots are on the map or where the green dots are on the map?"). The order of colours mentioned in the check question was also counterbalanced to ensure that children were not responding with the first colour they heard. Feedback was provided by stating if a child's response was correct, and the rules were explicitly restated for each sticker type regardless of the child's sticker choice (i.e., "That's right, in this game the orange dots tell you where the tiger stickers are hidden in the room and the green dots tell you where the turtle stickers are hidden in the room" or "Remember, in this game the orange dots tell you where the tiger stickers are hidden in the room and the green dots tell you where the turtle stickers are hidden in the room"). Children were given three attempts to correctly answer the check question, with corrective feedback after each attempt, before proceeding to the test trials (all participants successfully responded to the question by the third attempt). For each of the test trials children were asked to point to where their sticker of choice was hidden without touching anything in the room. This was done to ensure that children did not inadvertently receive feedback from the task itself. They were made aware that they would look for the stickers after they had looked at all of the maps.

In the colour-arbitrary version, children were told that dots of arbitrary colours (i.e., not otherwise seen in the task) indicated where the stickers were hidden in the room (see Appendix G). Despite which sticker was chosen, both stickers and corresponding dot colours were explained. For example, in this version, blue dots showed were orange tiger stickers were hidden in the room and pink dots indicated the location of the green turtle stickers. Once again, children were provided with a legend throughout the entire task to help them remember which of the coloured dots indicated where each kind of sticker was hidden. Also similar to the colour-match version, a check question was asked and feedback was once again provided by stating if a child's response was correct and reminding the child of the rules. As above, if the child's response to the check question was incorrect, the question was repeated to a maximum of three times (with corrective feedback following each time) and all children successfully responded by the third attempt.

The colour-conflict version was similar to the other two versions; however, in this task children were told that the stickers 'got mixed up' when they were hidden in the room (see Appendix H for the exact phrasing used). The experimenter once again had the participants choose between two types of stickers, but in this version children were told that the dots matching the colour of their chosen sticker type showed where the alternate stickers were hidden. For example, if a child chose to look for green turtle stickers, the experimenter explained that the orange dots on the map showed where the green turtle stickers were hidden in the room and the green dots on the map showed where the orange tiger stickers were hidden in the room. Again, a legend was placed on the table and the participant was asked a check question. As above, corrective feedback was provided and the question was asked up to three times. In the event that children were unable to correctly answer the question, they were corrected and reminded of the rules before continuing to test trials (four participants fell into this category).

The test trials consisted of eight maps which each child used to locate eight stickers in the room. Each map contained two coloured dots, one which indicated where the sticker that the child was looking for was hidden, and one which indicated where the alternate sticker could be found. The results of a previous study showed that children were able to successfully use a symbol to pinpoint the sticker's hiding place (Astle et al., 2009). In that study, errors occurred because children attended to the symbol which was in fact the representation for the alternate sticker. Given that children were using the symbols to find the stickers, they were looking to one of two locations and rarely committing *random* errors (i.e., they were rarely pointing to locations not shown by one of the two symbols on the maps). This binomial response pattern allowed me to score children's answers with greater reliability because I monitored responses to one of two locations the vast majority of the time. Based on the binomial distribution of responses, a scoring criterion of at least 7/8 was implemented to determine if performance was significantly better than chance.

For each trial in the colour-match version, successful participants were required to locate the coloured dot on the map which matched the colour of the sticker they were looking for and then point to where that sticker was hidden in the room. To be successful in the colour-arbitrary version, children needed to attend to the coloured dot which corresponded with their sticker choice and use that location to find the desired sticker. Finally, in the colour-conflict version, successful participants were required to find the coloured dot which matched the colour of the sticker they were not looking for and use that location to find where the sticker of choice was hidden in the room. Once the child pointed to what they believed were the hiding places of all eight stickers and responses were recorded, stickers were retrieved from the model room and given to the child regardless of their level of success on the task.

In conjunction with this task a battery of memory, ICC, and receptive vocabulary tasks was administered. The specific tasks were: Forward Digit Span (short-term memory), Counting and Labeling (verbal WM), Corsi Span (spatial WM), Dimensional Change Card Sort (ICC), Black/White Stroop (ICC), modified NEPSY-II Inhibition Task (ICC), and Peabody Picture Vocabulary Task – III (receptive language). I will describe each in turn.

Memory tasks.

Forward Digit Span. The Forward Digit Span (Carlson et al., 2002) measures memory by having children repeat various strings of numbers spoken by the experimenter (see Appendix J). The children were told that they would hear numbers, and were to say them back the same way that they heard them. The strings consisted of two numbers for each of the two practice trials (with feedback) and the first two test trials (without feedback). Success on the first two test trials led to the next two trials where the strings contained three numbers. Strings continued to increase in length by one with every two test trials, and the task was terminated when children were unable to correctly repeat both strings in a set (i.e., strings of the same length). Responses were recorded and tallied, with each correct test trial being valued at 0.5, to produce a raw score.

Counting and Labeling. Counting and Labeling (Gordon & Olson, 1998) is a measure of verbal WM which requires children to count and label small toys (see Appendix K). The experimenter demonstrated by first naming three small toys (e.g., "tree, gift, cow"), then counting them ("one, two, three") and finally naming and counting them at the same time (e.g., "one is a tree, two is a gift, three is a cow"). The child then followed these three steps for two test trials. Participants were only scored on their ability to count and label at the same time, and were given a score of one for answering correctly or zero for answering incorrectly for each of two test trials and a final score was tallied.

Corsi Span. The Corsi Span (Rasmussen & Bisanz, 2005) is a child-friendly version of the Corsi Blocks task in which an experimenter presents a child with picture of nine identical lily pads randomly dispersed (see Appendix L). In this task, children were told to pretend that their fingers were frogs jumping from lily pad lily pad. They were asked to watch carefully which lily pads the experimenter's frog jumped on and then jump on the lily pads in the same way. The first two trials involved jumping on only two lily pads, and feedback was provided. From that point on, feedback was not provided and the number of lily pads jumped on by the experimenter increased by one every two trials. Trials were administered until the child was unable to successfully respond to two trials of equal length. The participant's responses were recorded and their score was calculated based on a value of 0.5 for each correct trial.

Inhibitory control-conflict tasks.

Dimensional Change Card Sort. The Dimensional Change Card Sort (DCCS) was created by Frye et al. (1995) as a modification of the Wisconsin Card Sort to make the task child-friendly (a detailed description of the task was presented on page 28). The task measures inhibitory control-conflict by first having the children sort cards on one dimension (i.e., colour) and then switch to sorting on a previously irrelevant dimension (i.e., shape; see Appendix M). An accurate response is sorting the card on the dimension outlined by the experimenter; an inaccurate response is typically the result of failing to switch and occurs when a participant continues to sort the card on the previously relevant dimension. Eight pre-switch and eight post-switch trials were administered and scored separately. According to the bimodal distribution, performance was categorized as pass/fail and children were required to correctly sort a minimum of 7/8 trials to be considered performing better than chance.

Black/White Stroop. The Black/White Stroop task (Podjarny et al., 2008) is a simplified version of the of the Day/Night Stroop task (Gerstadt et al., 1994). The task involves children being shown a series of black and white cards. If shown a black card, children were asked to say "white" and if shown a white card, the correct response was "black" (see Appendix N). Children completed up to three practice trials with feedback and 21 test trials without feedback. Each trial involved inhibiting the instinctive response (i.e., saying "black" when shown a black card) and responding with a conflicting response (i.e., saying "white" when shown a black card). Children's responses were recorded and scored zero for inaccurate responses and one for accurate responses. Scores were tallied out of 21.

Modified NEPSY-II Inhibition Task. The task used is a modification of the NEPSY-II Inhibition Task and involves children being presented an array of black and white circles and squares (in no particular pattern). The first portion of the task requires children to follow along with a pointer and name each shape. Eight practice trials were administered with feedback prior to the 40 test trials (five rows of eight). Children were scored on trials attempted, correct responses, and self-corrected responses. Once children completed the naming portion of the task, they were instructed that they would then be playing the opposites game. Children viewed the same shapes again, however this time they were asked to say "circle" when they saw a square, and say "square" when they saw a circle. Similar to the Black/White Stroop, children were required to inhibit a prepotent response (i.e., saying "circle" when a circle is presented) and instead provide a conflicting response (i.e., saying "square" when a circle is presented). Once again, they completed eight practice trials with feedback and 40 test trials without feedback. Test trials were once again scored on accuracy. For both the naming and opposites versions, children were scored on their first full-word response and scores were tallied based on the ratio of correct responses out of trials completed. Errors were classified based on whether or not they were self-corrected by the participant, and an overall error score as well as a self-corrected error score was tabulated (see Appendix O).

Receptive Language Measure.

Peabody Picture Vocabulary Test – Third Edition (PPVT-III). The PPVT-III (Dunn & Dunn, 1997) was used to measure vocabulary level of participants. This standardized measure involves children viewing an array of pictures and indicating which picture matches the word spoken by the experimenter. The task began with two to six practice trials where the child was told to look at all four pictures on the page and point the picture of the word the experimenter said. Participants were provided with feedback during the practice trials and instructed that if at anytime they were uncertain of the correct response, they should point to what they thought was the best picture of the word. The following test trials were arranged in sets of 12 by increasing difficulty. Children began at the set at which they were able to correctly identify at least 11 out of 12 pictures and continued through the task until they had at least eight errors in one set. A raw score was calculated by subtracting the number of errors a participant made from the ceiling item they reached in the task.

Results

Prior to conducting the main analyses to examine performance on the symbol tasks, preliminary analyses were conducted to determine whether the two groups of participants were matched on all common measures. Thirty-three children received the colour-arbitrary version (21 in the first session, 12 in the second) and 36 children received the colour-conflict version of the symbol task (19 in the first session, and 17 in the second). The two groups of participants did not differ on any of the individual difference measures, except that those in the colour-conflict group performance better on the DCCS (using pass/fail scores), χ^2 $(1, N = 69) = 6.39, p = .011$. Furthermore, the two groups did not differ in age or gender, and there were no order effects, therefore these variables were not considered in subsequent analyses (see Appendices P and Q for details).

While the age range of the sample was fairly constrained (range was 47 – 61 months), it is still possible that there were age effects with the older children having more success on the tasks. In order to test for this possibility, the sample was split into two groups with the median age as the dividing point (median = 54.00 months). This resulted in two age groups, as seen in Table 2. To examine differences in performance on all measures between the two age groups, a series of independent samples t-tests were conducted. The performance of the younger children did not significantly differ from that of older children on any of these measures, therefore the sample was treated a single age group.

Table 2

Age Groups According to Median Split

Group (sample size)	Mean (SD)	Range
Younger group (33)	49.73(1.89)	47 – 53
Older group (36)	56.92(2.06)	54 – 61

Note. Age is reported is months.

Prior to testing the hypotheses for the present study, distributions of performance on all of the measures were examined. For distributions of performance on memory, ICC, and vocabulary tasks see Appendix R, and for normality statistics see Appendix S. Given that skewness and kurtosis values were within the recommended +/-2 range (Tabachnick & Fidell, 2006) and therefore were not extreme, that data was analyzed using raw scores.

Distribution of performance scores on the colour-match and colour-arbitrary versions were negatively skewed, whereas the colour-conflict version showed a bimodal distribution of scores. The distributions of scores on the three different versions of the symbol tasks are shown in Figures 1 through 4 (with Figures 1 and 2 pertaining to participants in the colour-arbitrary group whereas Figure 3 and 4 pertain to those in the colour-conflict group).

Figure 1

Performance on the Colour-Match Symbol Task for Children in Colour-Arbitrary Group

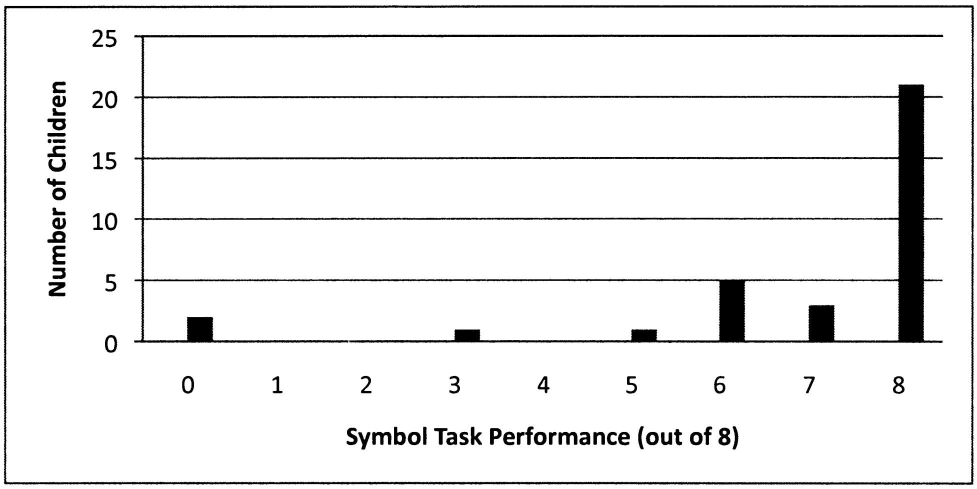


Figure 2

Performance on the Colour-Arbitrary Symbol Task

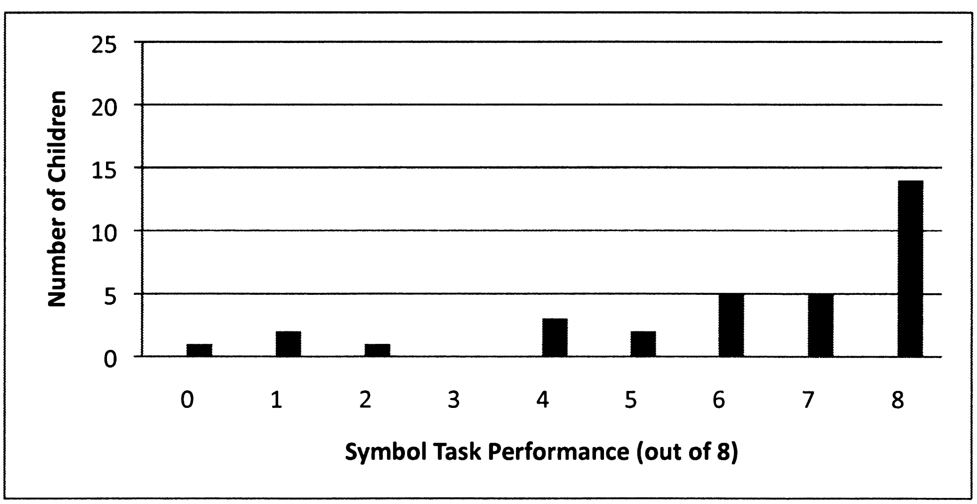


Figure 3

Performance on the Colour-Match Symbol Task for Children in Colour-Conflict Group

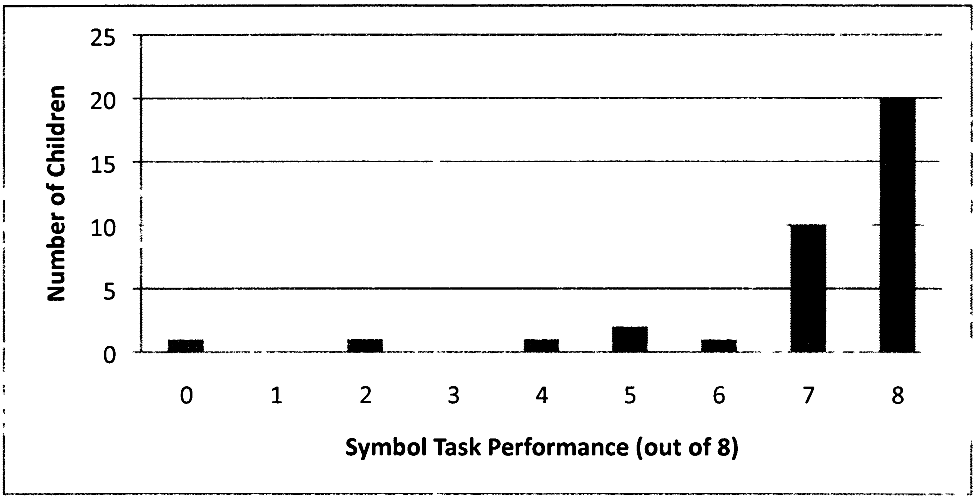
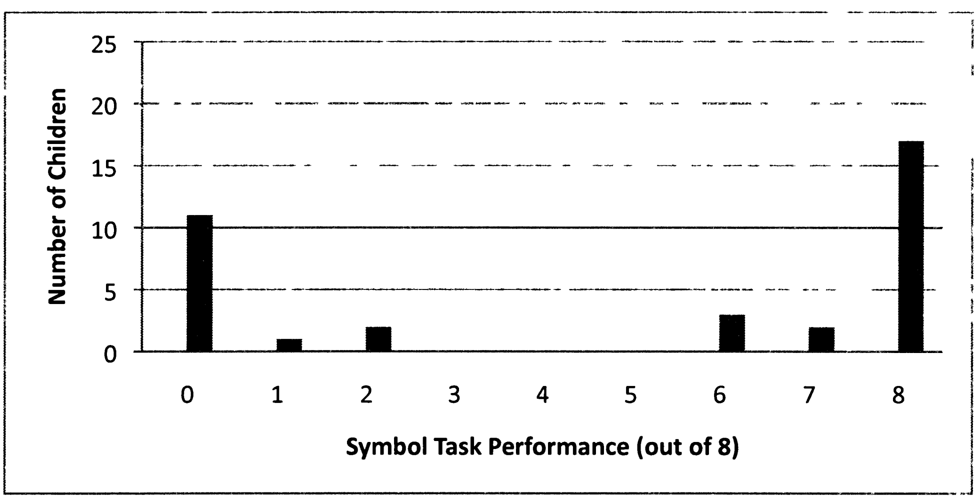


Figure 4

Performance on the Colour-Conflict Symbol Task



Comparing Performance Across the Symbol Tasks

To compare performance on the three different versions of the symbol task, a 2 x 2 mixed-design analysis of covariance (ANCOVA) was conducted with symbol task (match or non-match) as the within-subjects factor, and group (arbitrary or conflict) as the between-subjects factor. Recall that in the preliminary comparison of the two groups it was found that the participants in the colour-conflict group had higher DCCS scores, therefore DCCS performance was included as a control. Means are shown in Table 3.

Table 3

Mean Performance on Symbol Tasks

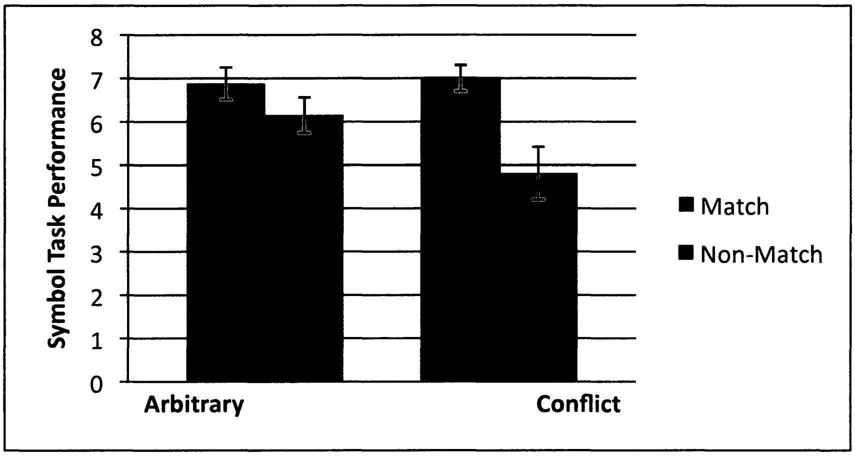
Group (sample size)	Match version Mean (SD)	Non-matching version Mean (SD)
Arbitrary (33)	6.88(2.12)	6.15(2.35)
Conflict (36)	7.00(1.79)	4.81(3.67)

Note. Performance is total score out of 8.

The first hypothesis was that children would be most successful on the colour-match version of the symbol task (as opposed to the other two versions). This is supported by considering the pattern of results as evident in the graphs above. Furthermore, a significant main effect of symbol task, $F(1, 67) = 17.27, p < .001, \eta_p^2 = .21$, indicates that children performed better on the colour-match ($M = 6.94, SD = 1.94, MSE = .23$) than on the non-match versions ($M = 5.45, SD = 3.16, MSE = .38$) of the task. A significant interaction, however, between symbol task and group, $F(1, 67) = 4.36, p = .041, \eta_p^2 = .06$, indicates that the degree of this difference depends on whether the non-match version is arbitrary or conflict. As can be seen in Figure 5, the difference between performance on the colour-match and the colour-conflict versions is much larger than the difference between the colour-match and the colour-arbitrary versions. In fact, a specified contrast demonstrates that the difference between the colour-match and colour-arbitrary version of the symbol task is not significant, $F(1, 68) = 1.60, p = .221$.

Figure 5

Interaction between Symbol Task and Participant Group



The second hypothesis proposed that performance on the colour-arbitrary version would be better than performance on the colour-conflict version. Results indicated that when controlling for DCCS, children who received the colour-arbitrary symbol task performed significantly better those who received the colour-conflict symbol task, $F(1, 66) = 4.33, p = .041$. This result supports the second hypothesis.

Contributions of Memory and Inhibitory Control-Conflict

To test the final two hypotheses, performance on the versions of the symbol task was examined in terms of correlations with memory and ICC. Also, contributions of memory and ICC to performance on symbols tasks were considered through a regression analysis. Prior to discussing the relations with the symbol tasks, correlations among measures of memory, ICC tasks, and the PPVT, will first be considered. Following this, I will examine how performance on these measures relate to performance on the symbol task, specifically how the colour-arbitrary version correlates with measures of memory and how the colour-conflict version correlates with measures of ICC.

Using the entire sample, the zero-order correlations among the cognitive measures (memory, ICC, and PPVT) showed that many of the tasks were inter-correlated (using raw scores; see Table 4). Across the whole sample, age (measured in months) was not significantly correlated with performance on the PPVT, memory measures, ICC tasks, the colour-match version or colour-arbitrary version of the symbol task. The only significant correlation with age was performance on the colour-conflict version of the symbol task ($r = .34$, $p = .042$). Therefore, it was not necessary to control for age when examining correlations.

Table 4

Correlations among Measures of Memory, Inhibitory Control-Conflict, and Language

		Measure	1	2	3	4	5	6	7
Memory	1	Forward Digit Span	---	.41**	.48**	.27*	.40**	.27*	.36**
	2	Counting & Labeling		---	.43**	.35**	.04	.30*	.48**
	3	Corsi Span			---	.23	.20	.25*	.32**
Inhibitory Control-Conflict	4	DCCS				---	.23	.36**	.31**
	5	Black/White Stroop					---	.30*	.18
	6	NEPSY Inhibition						---	.15
Language	7	PPVT							---

Note. * $p < .05$. ** $p < .01$.

As evident in Table 4, performance on many of the cognitive tasks are highly correlated with performance on the PPVT. For this reason, it is important to control for PPVT (raw scores) to determine which correlations are the result of relations between the tasks themselves and which are spurious due to relations with general language ability. Even after controlling for PPVT score, the memory scores correlate with each other and most ICC scores correlate with each other. The results of this more stringent correlational analysis are reported in Table 5.

Table 5

Partial Correlations between Measures of Memory and Inhibitory Control-Conflict, Controlling for General Language Ability

		Measure	1	2	3	4	5	6	7	8	9
Memory	1	Forward Digit Span	---	.29*	.41**	.18	.37**	.23	.19	.13	.18
	2	Counting & Labeling		---	.34**	.25*	-.06	.26*	.14	.45*	.35*
	3	Corsi Span			---	.15	.15	.22	.39**	.48*	.24
Inhibitory Control-	4	DCCS				---	.18	.34**	.21	.09	.41*
Conflict	5	Black/White Stroop					---	.29*	.14	.13	-.06
	6	NEPSY Inhibition						---	.22	.24	-.16
Symbol Task	7	Colour-match symbol task							---	.53**	.21
	8	Colour-arbitrary symbol task								---	---
	9	Colour-conflict symbol task									---

Note. * $p < .05$. ** $p < .01$.

To better understand the unique skills predictive of performance on the versions of the symbol task, the participants were analysed in terms of their performance on the symbol task in relation to measures of memory and ICC. Although performance on the colour-match version was expected to be near ceiling, the partial correlation (while controlling for PPVT) with scores on the Corsi Span was significant ($df = 66$, $pr = .39$, $p = .001$). The third hypothesis was that there would be a significant relation between performance the colour-arbitrary symbol task and memory measures. This is supported by significant partial correlations with the Corsi Span ($df = 30$, $pr = .48$, $p = .005$), and Counting and Labeling ($df = 30$, $pr = .45$, $p = .011$). The fourth hypothesis was that performance on the colour-conflict symbol task would be correlated with performance on ICC tasks. The partial correlation between scores on the colour-conflict task and DCCS was significant ($df = 33$, $pr = .41$, $p = .015$), supporting this hypothesis by demonstrating a significant relation between the performance on the conflict version and the DCCS as a measure of ICC.

Although correlations are helpful in determining the role of memory and ICC in children's performance on the non-matching symbol tasks, there are other analyses which can be considered. Recall that performance on the memory and ICC tasks themselves are inter-correlated, likely due to the similar cognitive demands made by each. Given that commonalities exist between multiple measures of the same construct (as evidenced by the inter-correlations), the data can be reduced through a principal component analysis. The goal of a principal component analysis is to express more than one variable as a single factor. This allows for a clearer examination of the relative contributions of memory and ICC by capturing the common elements of the corresponding measures for each. These common elements serve as more accurate representations of the skills as they pinpoint the overlap among tasks. Therefore, for the present study, a principle component analysis was performed and the factors for memory and ICC were extracted as purer measures for the constructs.

For memory, performance on the Forward Digit Span, Counting and Labeling, and Corsi Span were entered into the analysis and one component was extracted. For ICC, performance on the DCCS, Black/White Stroop, and modified NEPSY-II Inhibition Task were entered into a separate analysis and once again one component was extracted. The extraction values indicate the proportion of each variable's variance (in this case, the individual measures) explained by the principle component (i.e., memory or ICC). Ideally, according to Kaiser's criterion, these extraction values sum to an eigenvalue greater than one (Fabrigar, MacCallum, Wegener, & Strahan, 1999). Both the memory and ICC factors meet this criterion as found in Tables 6 and 7.

Table 6

Extraction Values for Measures of Memory and Inhibitory Control-Conflict

Factor	Measure	Extraction Value
Memory	Forward Digit Span	.64
	Counting and Labeling	.59
	Corsi Span	.66
Inhibitory Control-Conflict	DCCS	.53
	Black/White Stroop	.45
	NEPSY Inhibition	.61

Table 7

Eigenvalues and Variance Accounted for by Memory and Inhibitory Control-Conflict Factors

Factor	λ	% of Variance
Memory	1.89	63
Inhibitory Control-Conflict	1.60	53

To examine the contributions of memory and ICC on performance for the three different versions of the symbol tasks, scores were analysed using linear regression. Because the factors for memory and ICC were correlated, $r(67) = .45, p < .001$, each factor was considered in a separate regression. This was done to examine the roles they each play and avoid violating the multi-collinearity assumption. First, the colour-match version of the symbol task was examined in terms of memory and ICC contributions above and beyond age and PPVT score. To do so, age, and then the PPVT score were centered and then entered into a regression, following which memory and ICC factor scores were each entered in two separate regressions. Results indicate that performance on the colour-match version of the symbol task is significantly predicted by age (in months) and PPVT score, $F(2, 66) = 6.37, p = .003$. In addition to these contributions, memory is a significant predictor of colour-match symbol task performance, $\Delta F(1, 65) = 6.75, p = .012$ (see Table 8). Furthermore, the memory factor score was significantly correlated with performance on the colour-match version of the task, while controlling for age and PPVT score, $r(65) = .31, p = .012$.

Table 8

Memory as a Predictor of Matching Symbol Task Performance

Variable	Model 1 B	Model 2 B	Model 2 95% CI
Constant	6.97	6.95	[6.53, 7.37]
Age (in months)	.05	.01	[-.10, .11]
PPVT	.03**	.02	[.00, .04]
Memory		.65*	[.15, 1.15]
R^2	.16	.24	
F	6.37**	6.87***	
ΔR^2		.08	
ΔF		6.75*	

Note. $N = 69$. CI = confidence interval.
*$p < .05$. **$p < .01$. ***$p < .001$

In a separate regression, beyond the contributions of age and PPVT, ICC was also found to be a significant predictor of colour-match symbol task performance, $\Delta F(1, 65) = 4.41, p = .040$ (see Table 9). The ICC factor score was also significantly correlated with performance on the task, while controlling for age and PPVT score, $r(65) = .25, p = .040$.

Table 9

Inhibitory Control-Conflict as a Predictor of Matching Symbol Task Performance

Variable	Model 1 B	Model 2 B	Model 2 95% CI
Constant	6.97	6.96	[6.53, 7.38]
Age (in months)	.05	.03	[-.07, .14]
PPVT	.03**	.03**	[.01, .05]
ICC		.47*	[.02, .92]
R^2	.16	.22	
F	6.37**	5.93**	
ΔR^2		.05	
ΔF		4.41*	

Note. $N = 69$. CI = confidence interval.
*$p < .05$. **$p < .01$.

For the two non-matching versions of the symbol task, performance was found to be predicted by four centered factors entered into the regression in the following order: age (in months), PPVT score, whether it was the colour-arbitrary or colour-conflict version, and performance on the colour-match version, $F(4, 64) = 7.38, p < .001$. However, in addition to these variables, memory was not a significant predictor of non-matching symbol task performance, nor was the interaction between memory and symbol task version (colour-arbitrary versus colour-conflict) significant (see Table 10).

Table 10

Memory as a Predictor of Non-Matching Symbol Task Performance

	Non-matching symbol task performance			
			Model 3	
Variable	Model 1 *B*	Model 2 *B*	*B*	95% CI
Constant	4.46	5.31	5.25	[1.86, 8.66]
Age (in months)	.22**	.18*	.17*	[.00, .34]
PPVT	.03	.02	.02	[-.02, .05]
Arbitrary or Conflict Condition	-1.46*	-1.57*	-1.58*	[-2.87, -.28]
Colour-match Performance	.48*	.38*	.38	[.00, .77]
Memory		.70	.73	[-.10, 1.56]
Memory* Condition			.32	[-1.03, 1.68]
R^2	.32	.35	.35	
F	7.38***	6.67***	5.53***	
ΔR^2		.03	.00	
ΔF		2.96	.23	

Note. $N = 69$. CI = confidence interval.
*$p < .05$. **$p < .01$. ***$p < .001$

In a separate regression, ICC was investigated as a potential predictor of non-matching symbol task performance. The regression analysis showed that the ICC factor did not significantly predict performance on the non-matching versions of the task (above and beyond the contributions of age, PPVT score, symbol task version, and performance on the colour-match version). Furthermore, there was not a significant interaction between ICC and version of symbol task (see Table 11).

Table 11

Inhibitory Control-Conflict as a Predictor of Non-Matching Symbol Task Performance

	Non-matching symbol task performance			
			Model 3	
Variable	Model 1 *B*	Model 2 *B*	*B*	95% CI
Constant	4.46	4.36	4.38	[.79, 7.98]
Age (in months)	.22**	.22**	.22**	[.06, .39]
PPVT	.03	.03	.03	[-.01, .06]
Arbitrary or Conflict Condition	-1.46*	-1.43*	-1.45*	[-2.85, -.05]
Colour-match Performance	.48*	.49*	.48*	[.10, .87]
ICC		-.06	-.01	[-.82, .80]
ICC* Condition			.24	[-1.26, 1.75]
R^2	.32	.32	.32	
F	7.38***	5.82***	4.79***	
ΔR^2		.00	.00	
ΔF		.02	.11	

Note. $N = 69$. CI = confidence interval.
*$p < .05$. **$p < .01$. ***$p < .001$

Another approach for examining the contributions of memory and ICC is to categorize children's performance into pass/fail scores on all three versions of the symbol task, and investigate whether memory and ICC discriminate between the categorized groups. To begin, participants were divided into three groups based on whether they passed (scoring significantly better than chance, 7/8 or 8/8), failed (scoring significantly worse than chance, 0/8 or 1/8), or performed at chance (scoring in the range of 2-6 inclusively, based on the binomial distribution for eight trials). Results show that while most children pass the colour-match version (78%), the proportion of passers decreases for the colour-arbitrary and the colour-conflict versions (58% and 53% respectively, see Table 12). Interestingly, although the proportion of children passing the colour-arbitrary and colour-conflict version is similar for both versions, the performance of the non-passers is quite different between the two groups. Of those children who did not pass the colour-arbitrary version, 78% performed at chance – suggesting that they experienced some level of confusion or uncertainty with the task. In contrast, of the children who did not pass the colour-conflict version, only 29% performed within the range of chance – suggesting that many children used a consistent, but incorrect strategy on the conflict trials.

Table 12

Percentage of Participants who Passed, Failed, or Performed at Chance on Symbol Tasks

Version	Passed	Failed	Chance
Colour-match[a]	78	4	17
Colour-arbitrary[b]	58	9	33
Colour-conflict[c]	53	33	14

Note. [a]$n = 69$. [b]$n = 33$. [c]$n = 36$.

The differences among these groups of participants can be explained by using the underlying dimensions – the discriminant functions. Therefore, a discriminant function analysis was performed by finding the linear combination that maximally discriminates the groups. This was used to predict each participant's group membership (i.e., whether they would pass, fail, or perform at chance) based on their performance on the PPVT, as well as measures of memory and ICC. Then, this predicted group membership was compared to their actual performance on the symbol tasks, and differences were considered.

According to the discriminant function analysis, participants' performance on each of the symbol tasks was predicted based on their performance on the PPVT and measures of memory and ICC. Of the 60 children predicted to pass the colour-match version, 51 participants did perform above chance. Furthermore, of the 22 participants expected to pass the colour-arbitrary version, 17 passed. Finally, 25 participants expected to pass the colour-conflict version, 17 of which were in fact successful. These predictions were fairly accurate, suggesting that these factors are indeed predictive of symbol task performance (see Table 13).

Table 13

Comparison of n's for Predicted Symbol Performance versus Actual Symbol Performance

Predicted Group	Colour-match[a]			Colour-arbitrary[b]			Colour-conflict[c]		
	Pass	Chance	Fail	Pass	Chance	Fail	Pass	Chance	Fail
Pass	**51**	7	2	**17**	4	1	**17**	3	5
Chance	3	**5**	1	2	**7**	1	0	**0**	0
Fail	0	0	**0**	0	0	**1**	2	2	**7**

Note. [a]$n = 69$. [b]$n = 33$. [c]$n = 36$.

Examination of Errors on the Symbol Task

A more qualitative approach to examining the errors children made on the symbol task is to consider the *types* of errors that were made. For the purpose of this analysis, errors were categorized into the three types: (1) choosing the location of the alternate sticker; (2) choosing a location with the same label as the location indicated by the symbol (e.g., the desired sticker is indicated as being hidden under a chair, but the incorrect chair is chosen); and (3) miscellaneous errors. The first type of error is interesting because it is an indication children understood that the symbol on the map showed them where to find the sticker in the room, and were able to use that information to point to where the sticker was located. The error occurred, however, because the child used the incorrect symbol to locate the sticker. The second type of error, choosing a location with the same label, is worth noting because although children understand the relation between the symbol and the referent, they fail to consider the geographical location of the sticker's hiding place. Finally, miscellaneous errors were less systematic than the other two types, and usually consisted of choosing various unmarked locations (e.g., pointing to a wall of the room). This type of error is informative because it could be due to carelessness or misunderstanding the task itself.

As shown in Table 14, the majority of errors in the colour-match version of the symbol task were to miscellaneous locations, with the rest split between choosing the alternate sticker location and choosing a location with the same label. Similarly, the majority of errors on the colour-arbitrary version were also miscellaneous. However, the remainder of the errors were due to choosing the alternate sticker location. In the colour-conflict condition, the majority of errors occurred when participants chose the alternate sticker location and relatively few errors were due to choosing miscellaneous locations (see Table 14 for a summary of percentages). A chi-square analysis of the raw scores revealed a significant difference in the distribution of alternate sticker and miscellaneous errors across the two non-matching versions, χ^2 $(1, N = 168) = 44.91, p < .001$.

Table 14

Percentages of Categorized Errors on Symbol Tasks

	Symbol Task Condition		
Error Type	Colour-match	Colour-arbitrary	Colour-conflict
Alternate Sticker	19	31	68
Location with same label	19	6	3
Miscellaneous	61	62	29

Discussion

The first goal of the present study was to examine children's ability to interpret symbols through their performance on symbol tasks with various levels of resemblance in the symbol-referent relation. To do so, symbols bearing colour-match, colour-arbitrary, and colour-conflict relations to their referents were presented in maps and were used to indicate the location of stickers hidden in a model room. Beyond comparing performance on the various versions of the symbol task, the second goal was to investigate how performance was influenced by memory and ICC. Given the links found in previous research, as well as the demands of the symbol task itself, it was expected that these skills would contribute to symbol task performance.

Comparing Performance Across the Symbol Tasks

The first hypothesis that performance would be best on the colour-match version of the symbol task was supported by the results of the version comparisons. This finding was expected given the high performance on a similar task in a previous study (Astle et al., 2009). The colour-match version is straightforward and the symbols resemble their referents; therefore, participants can more easily associate the symbol with the referent. Nevertheless, the colour-match version was significantly correlated with performance on the Corsi Span, suggesting that spatial WM is a contributing factor.

The finding that performance was highest on the colour-match task, however, as mentioned above, should be interpreted with caution given the significant interaction with whether participants received the colour-arbitrary or colour-conflict symbol task. A comparison of performance on the colour-match and colour-arbitrary versions of the task demonstrated that the difference is was not significant and therefore it becomes evident that the significant main effect of colour-match versus non-match symbol task is driven by the difference in performance between the colour-match and colour-conflict tasks.

Recall that it was hypothesized that performance would be the poorest on the colour-conflict version. It was immediately evident that the colour-conflict version was more difficult than the colour match (as seen in Figures 3 and 4, as well as the discussion above). Although less obvious, the difference in performance between the colour-conflict and colour-arbitrary versions was also significant. The poor performance on the colour-conflict version of the task is evidence for the difficulty children experience when interpreting symbols which conflict with their referents. The difficulty with this task makes theoretical sense given that children must not only recognize that the symbol does not match its referent, but that it conflicts in some way. Overcoming the conflicting response for the colour-conflict version of the symbol task will be discussed in more detail in the discussion of the fourth hypothesis regarding the relation between performance on this version of the task and ICC.

The lower performance on the conflict task is consistent with Myers and Liben's (2008) finding that five- to eight-year-olds struggle when using symbols which conflict with their referents. Furthermore, Myers and Liben found that once removing this conflict through the use of arbitrary symbols (the neutral condition of their *map-intent* task) children did not prefer either colour dot. While children were more successful after the elimination of conflict, they still experienced some difficulty applying knowledge of the creator's intentions. The higher performance on my colour-arbitrary symbol task is likely due to different task demands than the Myer's and Liben task, as my study examines the ability to use arbitrary symbols to locate hidden objects as opposed to understanding intention.

The various versions of the symbol task were designed to investigate levels of resemblance in the symbol-referent relation. It was expected that performance on the tasks would differ depending on whether symbols matched their referents, were arbitrary, or were in conflict. However, performance was only significantly lower (relative to the matched condition) when symbols were in conflict with their referents. The finding that performance on the match version was not different from the arbitrary version suggests that for four-year-olds to achieve success on symbol tasks, it is not necessary for the symbols to match their referents. Rather, for most children, success can be achieved provided that symbols and their referents are not in conflict with each other.

Contributions of Memory and Inhibitory Control-Conflict

The third hypothesis predicted a significant correlation between measures of memory and performance on the colour-arbitrary version of the symbol task. This was partially supported through significant partial correlations with measures of both verbal and spatial working memory, after controlling for language. However, the contribution of memory is more complex given that in the regression analysis it failed to predict performance on the arbitrary version of the task after controlling for performance on the colour-match version. This finding (or lack thereof) is likely the result of performance on the colour-match version being correlated with the memory factor score. Therefore by controlling for performance on the colour-match version, memory is indirectly being controlled for as well. This control for colour-match task performance is important because it allows for a more accurate investigation of performance specific to the non-matching versions of the task. However, once applying this control, memory does not account for additional differences in performance on the colour-arbitrary version.

One finding that qualified my prediction of the contribution of memory was the role it plays in the colour-match version of the symbol task. The regression analysis revealed that memory was a significant predictor of colour-match symbol task performance, above and beyond the contributions of age and PPVT score. Although the colour-match version of the symbol was designed to make relatively minimal memory demands (compared to the other two versions of the task), the results revealed that memory is still required for success on the task. Upon reflection, it is clear that this is a sensible finding. To be successful on even the most basic version of the symbol task children must remember not only which symbol represents which referent (short-term memory), but also which location is indicated on the map (spatial memory). This is evidence that memory is necessary for more than a particular type of representational task, but is also required for a broader understanding of representations.

The contribution of memory on colour-match symbol task performance is an interesting addition to research which already exists on tasks of a representational nature. While some previous research has found links between representational tasks and ICC (e.g., Sabbagh, Moses, & Shiverick, 2006; Carlson, Davis, & Leach, 2005), this study demonstrates that memory can also be a factor in symbol task performance. This finding implies that an important aspect of representational understanding is simply remembering the symbol-referent relation.

The fourth hypothesis was that performance on the colour-conflict version of the task would be correlated with performance on measures of ICC. This prediction was based on the demands specific to this version of the task as well as the role of ICC in understanding representations, as demonstrated through other studies. While this hypothesis was partially supported through a significant correlation between performance on the colour-conflict version of the task and performance on the DCCS, it was not correlated with the other measures of ICC.

Interestingly, ICC was found to be a significant predictor of performance on the colour-match version of the symbol task. Although this task does not necessarily have a *conflict* component, ICC is demonstrated as a cognitive skill which plays a role in symbolic understanding. As demonstrated by DeLoache's research, children must achieve representational insight and dual representation to be successful on representational tasks. As previously discussed, dual representation involves being able to see the object both as a thing itself and as a representation of something else. In this case, to be successful on the symbol tasks, children must not only see the symbols as coloured dots but also as representations of the stickers hidden in the room. To see a dot as a representation, children must inhibit the natural tendency to view it solely as thing in and of itself. Given the link between performance on the colour-match version of the symbol task and ICC, the ability to inhibit the prepotent response of seeing the symbol as a thing in and of itself, and instead see it as standing for something else, is a factor accounting for success on this task.

Although ICC was found to significantly contribute to performance on the colour-match version of the symbol task, the anticipated contribution to performance on the colour-conflict version was not significant. Similar to the above discussion of memory, this can also be explained by considering how the regression analysis first controlled for performance on the colour-match version to examine the contributions unique to the non-matching tasks. Given that the ICC factor score is significantly correlated to performance on the colour-match version, the results of the regression suggest not that ICC has no role in the colour-conflict task but rather that the contribution is not beyond what is seen for the matching task.

The role of ICC on the colour-match version of the symbol task expands on the contributions of ICC as seen in the review of related research. It is worth noting that previous research has investigated the role of ICC, but only on performance on representational tasks which require the inhibition of a prepotent response (e.g., in the moving word task children must inhibit the item they see on the picture and report the word they know to be written on the card; Bialystok & Martin, 2003). These studies have identified ICC as being correlated with performance on representational tasks, but they did not include a baseline version of their task as a control. My results indicated that any contribution of ICC on a conflicting version of the symbol task fell away once controlling for performance on the colour-match version. Therefore, I would predict that if participants from previous studies had first completed a straight-forward representational task which was used as a control, the partial correlation between ICC and the conflicting representational task would not be significant. The present study adds to research on representations by suggesting that ICC may not be specific to understanding symbols which conflict with their referents, but rather ICC plays a role in representational understanding more generally.

The discriminant function analysis found that contributions of both memory and ICC are evident in that they, in conjunction with PPVT score, can be used to discriminate among those who passed, failed, or performed at chance on all three versions of the symbol task. This further highlights the influence of memory and ICC on performance on the symbol tasks. This seems unexpected given that memory and ICC were not found to be significant predictors of performance on the non-matching versions of the task in the regression analyses. However, when considering which variables discriminate amongst the groups, each symbol task is considered individually. Therefore the colour-arbitrary and colour-conflict tasks are not being investigated in terms of what contributes to performance on these tasks specifically (i.e., performance on the colour-match version is not controlled for) but rather what contributes to performance on them in general. This suggests that when performance on the non-matching tasks is considered without first controlling for performance on the colour-match task, memory and ICC are contributing factors. This is further evidence that although the contributions of memory and ICC are not significant for the non-matching versions above and beyond the contributions for the colour-match version, these cognitive skills are nonetheless important for symbolic understanding.

Errors on Symbol Task

Although there were no hypotheses about the types of errors children would make on the versions of the symbol task, it was evident during testing that specific types of errors were more frequent than others. While working with the children, it became clear that the two most systematic types of errors were choosing the location of the alternate sticker and choosing a location with the same label as the location indicated on the map (i.e., choosing a different chair than the one indicated). Choosing the location of the alternate sticker was an expected error, especially given the demands of the non-matching versions of the symbols tasks. Choosing a location with the same name, however, was less expected and therefore particularly intriguing. This type of error suggests that children understand the map-room correspondence, and the symbol-sticker correspondence, yet choose the wrong location in the room. This could be the result of children seeing the map as a representation, but verbally encoding the information presented without making note of the geometrical correspondence. As mentioned in the review of research on maps, Liben and Yekel (1996) argue that maps should contain geometric correspondence to avoid children achieving success simply based on detecting correspondences. The frequency of this type of error in the present study supports Liben and Yekel's claim, especially given that the opportunity to make such an error occurs at most four times out of the eight trials for the symbol task (unlike the other types of errors which could occur during any of the eight trials).

Errors made based on a failure to encode spatial information make sense given the significant correlation between the colour-match version of the symbol task and performance on the Corsi Span, which highlights the importance of spatial WM. Furthermore, such errors are evident in research by Blades and Cooke (1994) who found that young three-year-olds were successful on model tasks when the hiding place was unique, however, these same children were unable to accurately distinguish the correct location when the hiding place was one of two identical locations. This suggests that while young children can make note of the correct location, they often neglect to consider the spatial relation needed to distinguish between identical locations.

Limitations

Although the results of the present study are informative in terms of children's understanding of the symbol-referent relation, there are limitations that need to be acknowledged. One of the main goals of the study was to monitor performance on symbol tasks across various degrees of symbol-referent resemblance. However, comparing across task versions was difficult given the different distributions of performance. Mean scores are not indicative of the bimodal performance on the colour-conflict version, however classifying performance as pass/fail for the colour-match and colour-arbitrary versions is misleading given that participants in each group may not be performing that differently from each other. Therefore, a variety of types of analyses needed to be conducted to most accurately examine performance differences.

It is also important to recognize that the hypotheses regarding contributions of memory and ICC were only partially supported, potentially due to limitations with the measures of these skills. Most of the tasks yielded little variability in performance, or distributions of performance were either negatively skewed or bimodal. Although these measures are not ideal, given the lack of other appropriate measures in the field, the best options were used. If more sensitive measures had been available to assess these cognitive skills in a manner that is less categorical, associations with performance on the different versions of the symbol task, if they exist, would have been more visible. In hindsight, younger participants should also have been included to allow for a greater distribution of scores.

Furthermore, memory and ICC were demonstrated as factors which discriminate among those who passed, failed, or performed at chance on the symbol tasks. However, it is unfortunate that a relatively small number of participants failed or performed at chance and therefore it was not possible to determine what predicted group membership. If the sample size had been larger or more varied, a more meaningful examination of errors could have been conducted.

Given the significant correlation between the memory and ICC factor scores, it is difficult to monitor each factor's contribution to performance on the symbol task. For example, it is possible that the significant contribution of ICC on the colour-match task is driven by other EF skills. This challenge applies to all research in this area regarding the inherent problems with EF and overlap among skills. Although the contributions of memory and ICC are above and beyond general language ability, they could reflective of other cognitive developments.

Future Research

While the present study sheds some light on children's understanding of symbols which match, are arbitrary, or conflict with the colour of their referent, there are still many aspects of children's representational understanding to be investigated. Although the colour-match version of the symbol task was primarily included as a control to then examine performance on the non-matching versions of the task, the matching task itself demonstrated associations with memory and ICC. Given these results, it would be worthwhile to take a closer look at the colour-match version of the task not only as a baseline for measuring variations of it, but also as a task which makes significant memory and ICC demands itself. Although the near-ceiling performance on this task for the present study did not allow such an investigation, future research could include younger participants to increase variability in performance.

The inclusion of younger participants, in conjunction with more sensitive measures of executive function, would also address the above mentioned lack of variability of measures of memory and ICC. Hopefully the future will see the development of more finely-tuned measures of executive function that will produce response patterns which will more closely approximate a normal curve. Having a larger spread of performance scores on all of the tasks will allow for a more accurate look at relations among measures and expand beyond what impacts performance of those who are doing well to those who are performing at all levels of the symbol task. Increasing the sample size is another approach for continuing to investigate what contributes to performance on the symbol task. Recruiting more children would likely increase the number of children who failed or performed at chance on the symbol tasks and therefore it might then be possible to determine which factors predict group membership.

Another area for future research to investigate is a wider range of symbol-referent variations. While the present study examined three variations of the symbol-referent relation, it would be interesting to further develop the conflict aspect of the task to monitor later-emerging symbol-referent understanding in older children. One approach would be to include the full-conflict task used in previous study (Astle et al., 2009) to further increase the difficulty of the task with older participants to continue to examine the role of contributing cognitive skills as well as further the investigation of what demands children can overcome at what age.

Another interesting line of research to be considered is children's production of symbols (as seen in the Myers and Liben *make-a-map* task) but with the varying degrees of resemblance (as seen in the present study). It would be of interest to continue to examine the contributions of memory and ICC, but on symbol tasks which involve children knowing the location of hidden objects and creating symbols to help others to find them. Given that Myers and Liben found children have greater success when producing symbols as opposed to interpreting them, it would be worthwhile to see how varying the level of resemblance in the symbol-referent relation (i.e., match, arbitrary, or conflict) impacts performance on such a task. While it is important to understand which levels non-iconicity children can handle when using symbols, the Myers and Liben study (2008) suggests that the situation in which a symbol is being used is another contributing factor, and I agree that it is one that bears further consideration.

Conclusions

Taken together, these findings expand on the results of a previous study (Astle et al., 2009) by not only investigating various levels of the symbol-referent relation but also by finding links with memory and ICC. This deepens our understanding of how children understand symbols as representations. From this study, we can conclude that four-year-olds understand the basic 'this stands for that' relation, as seen by their success on the map orientation trials as well as their responses to questions about which symbol they would attend to in the task. Therefore, something beyond representational insight and dual representation must be accounting for the variability in performance on the different versions of the symbol task. While children are often able to report which symbol stands for which referent, they experience some difficulty using them in context. This supports Bialystok's conclusion (1992b) that simply having knowledge of the symbol-referent relation is necessary but not sufficient for using this information to carry out an action. Furthermore, the present study highlights how even greater challenges are faced when attempting to use non-iconic symbols which have been assigned contextual meanings.

Of the three versions of the symbol task, performance on the colour-match task allowed for the richest understanding of the contributions of memory and ICC through the analyses conducted. The results presented above indicate that children with more developed memory and ICC skills are better at using symbols. While there is some support for the hypotheses that specific skills are related to specific tasks (i.e., memory is associated with the arbitrary version and ICC is associated with the conflict version), there is also evidence that these cognitive skills are related to symbolic understanding in general (as seen in the match task), addressing the much larger issue of children's cognition as a whole. Hopefully, this will spark future investigations of the contributions of cognitive skills to representational understanding. Together, research on how children understand various types of symbols, as well as what cognitive skills facilitate this understanding, can be applied to broaden our understanding of how children represent many aspects of their world.

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Appendix A

Consent Form: Daycare Program Coordinator

Winter 2009

Dear Program Coordinator

We are writing to invite your centre to participate in a research project being conducted at Carleton University The purpose of this research is to examine children's ability to extract information from maps This study has been approved by the Carleton University Ethics Committee for Psychological Research There are no potential physical or psychological risks for any of the participants

Children will participate in a number of games For example in one children use maps to find stickers hidden in a model room (which sits on a table top) Other games include repeating what the researcher has said (such as 3 numbers), sorting cards by shape and color, or pointing to pictures that the experimenter names (e g , point to the dog') Children usually enjoy these kinds of activities and will be given stickers as thanks (even if they decide to stop playing part-way through)

We will meet with each child twice for approximately 30 minutes each time (the sessions will be conducted by university students) The information collected in this study is confidential and will be coded such that a child's name is not associated with their responses and the information provided will be used for research purposes only

Participation in this experiment is completely *voluntary* Children will be asked if they want to participate, and if they don't, they will not be pressured into participating Children can stop playing our games at any time The researchers will be sensitive to the children at all times

The primary researcher, who will be working with the children is Andrea Astle, and she may be reached via email at aastle@connect.carleton ca The research supervisor is Dr Deepthi Kamawar and she may be reached at 613-520-2600, ext 7021 If you have any ethical concerns about this study, please contact Dr Monique Senéchal (Ethics Chair, Carleton University Ethics Committee for Psychological Research, 613-520-2600 ext 6026) Should you have any other concerns about this study, please contact Dr Janet Mantler (Chair, Dept of Psychology, 613 520 2600 ext 4173)

Your consent is required for your centre's participation in this project If you would like a summary of the research results once the study is completed, please contact Andrea However, please note that individual feedback regarding the children will not be provided

Thank you for your consideration

Sincerely,

Deepthi Kamawar, PhD
Professor of Psychology

Appendix A Continued

Consent Form: Daycare Program Coordinator

Understanding Maps
Department of Psychology
Institute of Cognitive Science
Carleton University

This document is our agreement to participate in the above research project that is to be conducted by Andrea Astle and Dr. Deepthi Kamawar from Carleton University.

We understand that the study will require two testing sessions, with children of appropriate ages, whose parents/guardians have given written consent for their children's participation in the research project. The children's participation is voluntary and no child will be made to participate. We also allow the children to familiarize themselves with the researchers during preliminary activities.

Name of Centre: ______________________________

Address: ______________________________

____

Signature: ____________________ Date: ______________

Name & Title: ____________________

Appendix B

Consent Form: Parents/Guardians (off-campus)

Winter 2009

Dear parent(s) or guardian(s),

As part of a current project on children's cognitive development, we are talking to children to get a better idea of how they understand how maps work. The study has been approved by the Carleton University Ethics Committee for Psychological Research and it involves no physical or psychological risks for the children who take part in it. In this letter, we will describe the project and request your permission for your child to participate. The purpose of an informed consent is to ensure that you understand the purpose of the study and the nature of your child's involvement.

Children will participate in a number of games. For example in one, children use maps to find stickers hidden in a model room (which sits on a table top). Other games include repeating what the researcher has said (such as 3 numbers), sorting cards by shape and color, or pointing to pictures that the experimenter names (e.g., 'point to the dog'). Children usually enjoy these kinds of activities and will be given stickers as thanks (even if they decide to stop playing part-way through).

We will meet with each child twice for approximately 30 minutes each time (the sessions will be conducted by university students). The information collected in this study is confidential and will be coded such that a child's name is not associated with their responses, and the information provided will be used for research purposes only.

Participation in this experiment is completely voluntary. Children will be asked if they want to participate, and if they don't, they will not be pressured into participating. Children can stop playing our games at any time .The researchers will be sensitive to the children at all times.

The primary researcher who will be working with the children is Andrea Astle, and she may be reached via email at aastle@connect.carleton.ca. The research supervisor is Dr. Deepthi Kamawar and she may be reached at 613-520-2600, ext. 7021. If you have any ethical concerns about this study, please contact Dr. Monique Sénéchal (Ethics Chair, Carleton University Ethics Committee for Psychological Research, 613-520-2600 ext. 1155). Should you have any other concerns about this study, please contact Dr. Janet Mantler (Chair, Dept. of Psychology, 613-520-2600 ext. 4173).

Your consent is required for your child's participation in this project. Kindly sign the attached consent form indicating whether your child may participate in this research and return it to your child's daycare. If you would like a summary of the research results once the study is completed, please contact Andrea. However, please note that individual feedback regarding the children cannot be provided.

Thank you for your consideration.

Sincerely,

Deepthi Kamawar, PhD

Appendix B Continued

Consent Form: Parents/Guardians (off-campus)

Carleton University Map Study

Carleton UNIVERSITY
Canada's Capital University

I have read the attached description of the study on cognitive development (understanding maps) and I understand the conditions of my child's participation. My signature indicates that I agree to let my child participate in the study.

Child's Name: ________________________________

Child's Date of Birth: Year 200___ Month ________ Day ________

Parent's/Guardian's Name: ____________________________

Signature. ______________________ Date. __________

Child's Teacher: __________________________

Please indicate the language(s) spoken at home and then please circle the ones that your child is fluent in: ____________ ____________ ____________

In our lab we conduct many other studies that children find quite enjoyable (usually in the form of games and stories). We provide free parking and a small 'thank-you' gift to the children.

May we contact you in the future to see if you are interested in having your child participate in other projects? All participation would be completely voluntary and you would be under no obligation to participate if we contact you.

____ Yes If yes, please provide phone number or email: ______________________

____ No

Other Children in the family

Child's Name: ______________________________

Date of Birth: year ______ month _______ day _______

Child's Name: ______________________________

Date of Birth: year ______ month _______ day _______

Child's Name: ______________________________

Date of Birth: year ______ month _______ day _______

Appendix C

Consent Form: Parents/Guardians (on-campus)

Winter 2009

Dear parent(s) or guardian(s),

As part of a current project on children's cognitive development, we are talking to children to get a better idea of how they understand how maps work. The study has been approved by the Carleton University Ethics Committee for Psychological Research and it involves no physical or psychological risks for the children who take part in it. In this letter, we will describe the project and request your permission for your child to participate. The purpose of an informed consent is to ensure that you understand the purpose of the study and the nature of your child's involvement.

Children will participate in a number of games. For example, in one game, children use maps to find stickers hidden in a model room (which sits on a table top). Other games include repeating what the researcher has said (such as 3 numbers), sorting cards by shape and color, or pointing to pictures that the experimenter names (e.g., 'point to the dog'). Children usually enjoy these kinds of activities and will be given stickers as thanks (even if they decide to stop playing part-way through).

We will work with each child for approximately 30 minutes, take a short break (approx. 10 minutes) and then work again for about 30 more minutes. The information collected in this study, including video recordings, is confidential and will be coded such that a child's name is not associated with his or her responses, and the information provided will be used for research purposes only. Further, only people directly involved in the research will have access to the recordings.

Participation in this experiment is completely voluntary. Children will be asked if they want to participate, and if they don't, they will not be pressured into participating. Children can stop playing our games at any time. The researchers will be sensitive to the children at all times.

The primary researcher who will be working with the children is Andrea Astle, and she may be reached via email at aastle@connect.carleton.ca. The research supervisor is Dr. Deepthi Kamawar and she may be reached at 613-520-2600, ext. 7021. If you have any ethical concerns about this study, please contact Dr. Monique Sénéchel (Ethics Chair, Carleton University Ethics Committee for Psychological Research, 613-520-2600 ext. 1155). Should you have any other concerns about this study, please contact Dr. Janet Mantler (Chair, Dept. of Psychology, 613-520-2600 ext. 4173).

Your consent is required for your child's participation in this project. Kindly sign the attached consent form indicating whether your child may participate in this research. If you would like a summary of the research results once the study is completed, please contact Andrea. However, please note that individual feedback regarding the children cannot be provided.

Thank you for your consideration.

Sincerely,

Deepthi Kamawar, PhD

Appendix C Continued

Consent Form: Parents/Guardians (on-campus)

Carleton University Map Study

Carleton UNIVERSITY
Canada's Capital University

I have read the attached description of the study on cognitive development (understanding maps) and I understand the conditions of my child's participation. My signature indicates that I agree to let my child participate in the study.

Child's Name: ________________________________

Child's Date of Birth: Year 200___ Month _______ Day _______

Parent's/Guardian's Name: ____________________________

Signature: _______________________ Date: ___________

Child's Teacher: ___________________________

Please indicate the language(s) spoken at home and then please circle the ones that your child is fluent in: ____________ ____________ ____________

In our lab we conduct many other studies that children find quite enjoyable (usually in the form of games and stories). We provide free parking and a small 'thank-you' gift to the children.

May we contact you in the future to see if you are interested in having your child participate in other projects? All participation would be completely voluntary and you would be under no obligation to participate if we contact you.

____ Yes If yes, please provide phone number or email: ______________________

____ No

Other Children in the family

Child's Name: ______________________________

Date of Birth: year ______ month _______ day _______

Child's Name: ______________________________

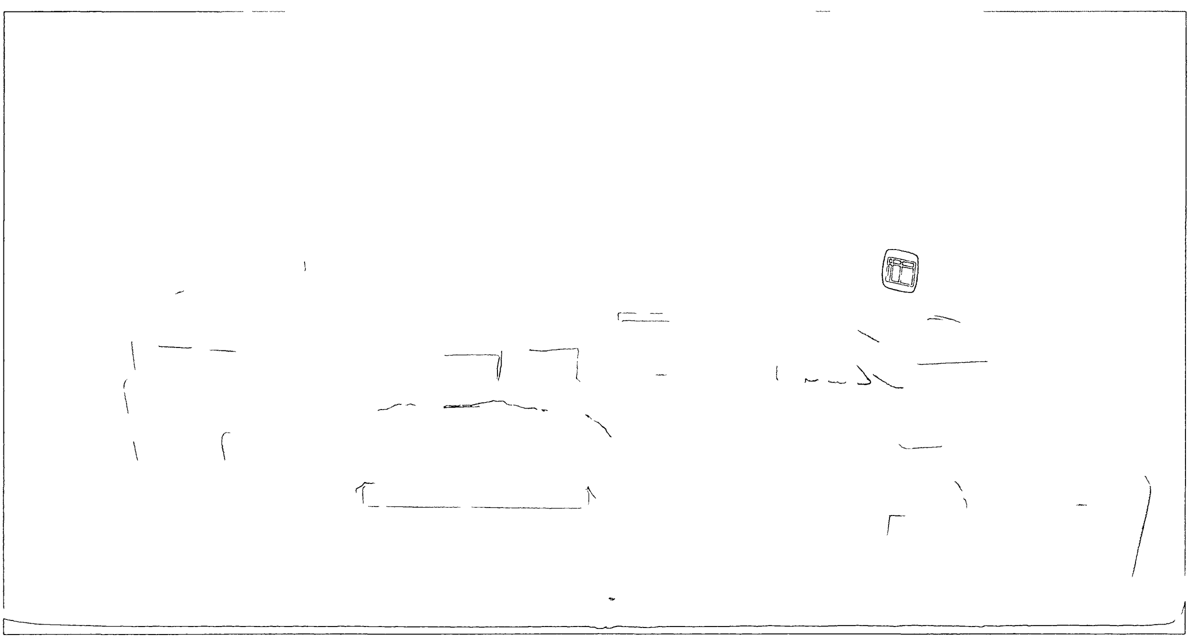
Date of Birth: year ______ month _______ day _______

Child's Name: ______________________________

Date of Birth: year ______ month _______ day _______

Appendix D

Photographs of Model Rooms (Symbol Task)



Appendix E

Maps of Model Rooms (Symbol Task)

Appendix F

Symbol Task – Colour-Match Version Protocol

Version A – Colour-Match **Bedroom**

Our Use-a-Map Task

See these four things? Can you show me the TIGER? ...TURTLE? ... LADY BUG? ... RUBBER DUCK? (*randomize; indicate participant's accuracy below*)

TIGER _______ TURTLE ________ LADY BUG _______ RUBBER DUCK ________

Now see these colours? Can you show me ORANGE? Alright, now can you show me GREEN? ... RED? ... YELLOW? ... BLUE? ... PINK? ... BROWN? (*randomize; indicate participant's accuracy below*)

ORANGE____GREEN____RED____YELLOW____BLUE____PINK____BROWN___

If correct: **Good job!**

If incorrect: **Good try, but this is the [*item*].** (*come back to item at end*)

If unable to identify the shapes, terminate map task.

Orientation

Okay, now we're going to do something else. Here's a map *(point to map)*. **This is a map of this room** *(motion to room)*. **See this here in the map** *(point to bed)*? **Look, here it is in the room** *(point)*. **So this in the map** *(point)* **is this in the room** *(point)*. **Look at the map again. See this here in the map** *(point to sofa)*? **Can you point to where this is in the room?**

Trial One: ________

If correct: **Good! You're right. This here in the map** *(point)* **is this here in the room** *(point)*.

If incorrect: **Good try, but actually, this here in the map** *(point)* **is this here in the room** *(point)*. **See? Let's try another one. See this here in the map** *(point to closet)*? **Can you point to where this is in the room?**

Trial Two: _______

If incorrect: **Good try, but actually, this here in the map** *(point)* **is this here in the room** *(point)*. **See? Let's try one more. See this here in the map** *(point to dresser)*? **Can you point to where this is in the room?**

Trial Three: _______

If incorrect: **Good try, but actually, this here in the map** *(point)* **is this here in the room** *(point)*. (*Continue to sticker choice)*

Appendix F Continued

Symbol Task – Colour-Match Version Protocol

Version A – Colour-Match **Bedroom**

Sticker Choice

Alright. Now we are going to play a game with maps. I have hidden some stickers in this room. I hid 2 kinds of stickers: ORANGE TIGERS and GREEN TURTLES *(show stickers)* **and your job is to find the kind that you like the most. Which kind of stickers do you like better?**

Orange TIGER Green TURTLE

Okay, to help you find the stickers I made a bunch of maps that tell you where to look for them. I used ORANGE and GREEN dots to show you where the ORANGE TIGER stickers and the GREEN TURTLE stickers are hidden.

Now your job is to look at a map and point to where the sticker is in the room. You're not going to touch anything in the room. You're just going to point to the place where the sticker is hidden. But, after we've looked at all the maps I will show you where the stickers are, and then you'll get to take them home.

Map Key

Show first map. **So on the maps, the ORANGE DOTS** *(point)* **tell us where the ORANGE TIGER stickers are hidden and the GREEN DOTS** *(point)* **tell us where the GREEN TURTLE stickers are hidden. And to help you remember, I made this** *(show legend).*

It says what I just told you. See, it says that the ORANGE DOTS *(point)* **on the map will tell you where to find the ORANGE TIGER stickers** *(point)*, **and that the GREEN DOTS on the map** *(point)* **will tell you where to find the GREEN TURTLE stickers** *(point).*

Check Question

Remember, you said that you want to look for the TIGER/TURTLE stickers *(point to appropriate sticker and maintain point).* **So, are you going to look for the TIGER/TURTLE stickers where the ORANGE DOTS are on the map or where the GREEN DOTS are on the map?**

Trial One: __________

If correct:	**That's right, in this game the ORANGE DOTS** *(point)* **tell you where the TIGER stickers** *(point)* **are hidden in the room and the GREEN DOTS** *(point)* **tell you where the TURTLE stickers** *(point)* **are hidden in the room.** *(continue to test trials)*
If incorrect:	**Remember, in this game the ORANGE DOTS** *(point)* **tell you where the TIGER stickers** *(point)* **are hidden in the room and the GREEN DOTS** *(point)* **tell you where the TURTLE stickers** *(point)* **are hidden in the room.**

Appendix F Continued

Symbol Task – Colour-Match Version Protocol

Version A – Colour-Match **Bedroom**

You are looking for the TIGER/TURTLE stickers, so are you going to look where the ORANGE DOTS are on the map or where the GREEN DOTS are on the map?

Trial Two: ________ *(Repeat again if incorrect)* Trial Three: ________

If incorrect after 3rd trial

Remember, in this game the ORANGE DOTS ***(point)*** **tell you where the TIGER stickers** ***(point)*** **are hidden in the room and the GREEN DOTS** ***(point)*** **tell you where the TURTLE stickers** ***(point)*** **are hidden in the room.** *(continue to test trials)*

We'll leave this here ***(place legend to side)*** **to help us remember all that.**

Test Trials

Okay, now I'm going to show you some more maps and you will point to where the TIGER/TURTLE sticker is hidden in the room. Remember, we're not going to touch anything in the room until we're done looking at all the maps.

Can you point to where a TIGER/TURTLE sticker is hidden in the room? *(indicate room with open wave)*

1 ________

2 ________

3 ________

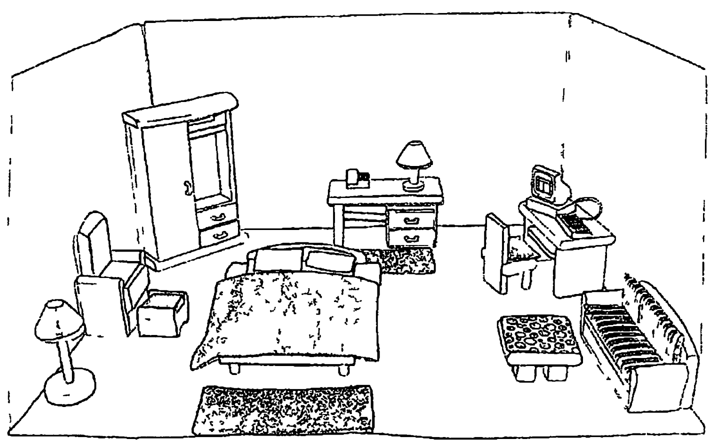
4 ________

5 ________

6 ________

7 ________

8 ________



1 = correct location *2 = alternate location* *3 = incorrect location*
Children are allowed to self-correct
Mark any incorrect locations (3) on the map

Appendix G

Symbol Task – Colour-Arbitrary Version Protocol

Version B – Colour-Arbitrary **Kitchen**

Our Use-a-Map Task

See these four things? Can you show me the TIGER? ...TURTLE? ... LADY BUG? ... RUBBER DUCK? *(randomize, indicate participant's accuracy below)*

TIGER _______ TURTLE ________ LADY BUG _______ RUBBER DUCK ________

Now see these colours? Can you show me ORANGE? Alright, now can you show me GREEN? ... RED? ... YELLOW? ... BLUE? ... PINK? ... BROWN? *(randomize, indicate participant's accuracy below)*

ORANGE____GREEN____RED____YELLOW____BLUE____PINK____BROWN___

If correct	**Good job!**
If incorrect	**Good try, but this is the [*item*].** *(come back to item at end)*
If unable to identify the shapes, terminate map task	

Orientation

Okay, now we're going to do something else. Here's a map *(point to map)* **This is a map of this room** *(motion to room)*. **See this here in the map** *(point to table)*? **Look, here it is in the room** *(point)*. **So this in the map** *(point)* **is this in the room** *(point)*. **Look at the map again. See this here in the map** *(point to TV stand)*? **Can you point to where this is in the room?**

Trial One ________

If correct	**Good! You're right. This here in the map** *(point)* **is this here in the room** *(point)*
If incorrect	**Good try, but actually, this here in the map** *(point)* **is this here in the room** *(point)* **See? Let's try another one. See this here in the map** *(point to cupboard)*? **Can you point to where this is in the room?**
Trial Two _______	
If incorrect	**Good try, but actually, this here in the map** *(point)* **is this here in the room** *(point)* **See? Let's try one more. See this here in the map** *(point to stove)*? **Can you point to where this is in the room?**
Trial Three _______	
If incorrect	**Good try, but actually, this here in the map** *(point)* **is this here in the room** *(point)* *(Continue to sticker choice)*

Appendix G Continued

Symbol Task – Colour-Arbitrary Protocol

Version B – Colour-Arbitrary **Kitchen**

Sticker Choice

Alright. Now we are going to play a game with maps. I have hidden some stickers in this room. I hid 2 kinds of stickers: RED LADY BUGS and YELLOW RUBBER DUCKS *(show stickers)* **and your job is to find the kind that you like the most. Which kind of stickers do you like better?**

Red LADY BUGS Yellow RUBBER DUCKS

Okay, to help you find the stickers I made a bunch of maps that tell you where to look for them. I used BROWN and BLUE dots to show you where the RED LADY BUG stickers and the YELLOW RUBBER DUCK stickers are hidden.

Now your job is to look at a map and point to where the sticker is in the room. You're not going to touch anything in the room. You're just going to point to the place where the sticker is hidden. But, after we've looked at all the maps I will show you where the stickers are, and then you'll get to take them home.

Map Key

Show first map. **So on the maps, the BLUE DOTS** *(point)* **tell us where the YELLOW RUBBER DUCK stickers are hidden and the BROWN DOTS** *(point)* **tell us where the RED LADY BUG stickers are hidden. And to help you remember, I made this** *(show legend).*

It says what I just told you. See, it says that the BLUE DOTS *(point)* **on the map will tell you where to find the YELLOW RUBBER DUCK stickers** *(point)*, **and that the BROWN DOTS on the map** *(point)* **will tell you where to find the RED LADY BUG stickers** *(point).*

Check Question

Remember, you said that you want to look for the LADY BUG/RUBBER DUCK stickers *(point to appropriate sticker and maintain point).* **So, are you going to look for the LADY BUG/RUBBER DUCK stickers where the BLUE DOTS are on the map or where the BROWN DOTS are on the map?**

Trial One: _________

If correct: **That's right, in this game the BLUE DOTS** *(point)* **tell you where the RUBBER DUCK stickers** *(point)* **are hidden in the room and the BROWN DOTS** *(point)* **tell you where the LADY BUG stickers** *(point)* **are hidden in the room.** *(continue to test trials)*

If incorrect: **Remember, in this game the BLUE DOTS** *(point)* **tell you where the RUBBER DUCK stickers** *(point)* **are hidden in the room and the BROWN DOTS** *(point)* **tell you where the LADY BUG stickers** *(point)* **are hidden in the room.**

Appendix G Continued

Symbol Task – Colour-Arbitrary Protocol

Version B – Colour-Arbitrary **Kitchen**

You are looking for the LADY BUG/RUBBER DUCK stickers, so are you going to look where the BLUE DOTS are on the map or where the BROWN DOTS are on the map?

Trial Two. __________ *(Repeat again if incorrect):* Trial Three: __________

If incorrect after 3rd trial:

Remember, in this game the BLUE DOTS *(point)* tell you where the RUBBER DUCK stickers *(point)* are hidden in the room and the BROWN DOTS *(point)* tell you where the LADY BUG stickers *(point)* are hidden in the room. [*continue to test trials*]

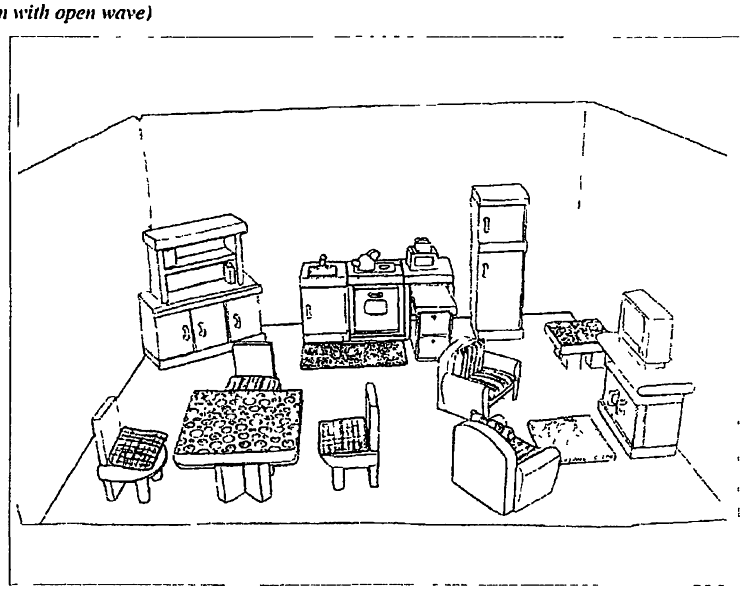
We'll leave this here *(place legend to side)* to help us remember all that.

Test Trials

Okay, now I'm going to show you some more maps and you will point to where the LADY BUG/RUBBER DUCK sticker is hidden in the room. Remember, we're not going to touch anything in the room until we're done looking at all the maps.

Can you point to where a LADY BUG/RUBBER DUCK sticker is hidden in the room?
(indicate room with open wave)

1. __________
2. __________
3. __________
4. __________
5. __________
6. __________
7. __________
8. __________



1 = correct location *2 = alternate location* *3 = incorrect location*
Children are allowed to self-correct.
Mark any incorrect locations (3) on the map.

Appendix H

Symbol Task – Colour-Conflict Version Protocol

Version B – Colour-Conflict **Kitchen**

Our Use-a-Map Task

See these four things? Can you show me the TIGER? ...TURTLE? ... LADY BUG? ... RUBBER DUCK? *(randomize; indicate participant's accuracy below)*

TIGER _______ TURTLE ________ LADY BUG _______ RUBBER DUCK ________

Now see these colours? Can you show me ORANGE? Alright, now can you show me GREEN? ... RED? ... YELLOW? ... BLUE? ... PINK? ... BROWN? *(randomize; indicate participant's accuracy below)*

ORANGE____GREEN____RED____YELLOW____BLUE____PINK____BROWN___

If correct: **Good job!**

If incorrect: **Good try, but this is the [*item*].** *(come back to item at end)*

If unable to identify the shapes, terminate map task.

Orientation

Okay, now we're going to do something else. Here's a map *(point to map)*. **This is a map of this room** *(motion to room)*. **See this here in the map** *(point to table)*? **Look, here it is in the room** *(point)*. **So this in the map** *(point)* **is this in the room** *(point)*. **Look at the map again. See this here in the map** *(point to TV stand)*? **Can you point to where this is in the room?**

Trial One: ________

If correct: **Good! You're right. This here in the map** *(point)* **is this here in the room** *(point)*.

If incorrect: **Good try, but actually, this here in the map** *(point)* **is this here in the room** *(point)*. **See? Let's try another one. See this here in the map** *(point to cupboard)*? **Can you point to where this is in the room?**

Trial Two: _______

If incorrect: **Good try, but actually, this here in the map** *(point)* **is this here in the room** *(point)*. **See? Let's try one more. See this here in the map** *(point to stove)*? **Can you point to where this is in the room?**

Trial Three: _______

If incorrect: **Good try, but actually, this here in the map** *(point)* **is this here in the room** *(point)*. *(Continue to sticker choice)*

Appendix H Continued

Symbol Task – Colour-Conflict Version Protocol

Version B – Colour-Conflict **Kitchen**

Sticker Choice

Alright. Now we are going to play a game with maps. I have hidden some stickers in this room. I hid 2 kinds of stickers: RED LADY BUGS and YELLOW RUBBER DUCKS *(show stickers)* **and your job is to find the kind that you like the most. Which kind of stickers do you like better?**

Red LADY BUGS Yellow RUBBER DUCKS

Okay, to help you find the stickers I made a bunch of maps that tell you where to look for them. I used RED and YELLOW dots to show you where the RED LADY BUG stickers and the YELLOW RUBBER DUCK stickers are hidden.

Now your job is to look at a map and point to where the sticker is in the room. You're not going to touch anything in the room. You're just going to point to the place where the sticker is hidden. But, after we've looked at all the maps I will show you where the stickers are, and then you'll get to take them home.

Map Key

But you know what? I got the stickers mixed up when I made these maps! *(show first map)* **So on the maps, the RED DOTS** *(point)* **tell us where the YELLOW RUBBER DUCK stickers are hidden and the YELLOW DOTS** *(point)* **tell us where the RED LADY BUG stickers are hidden. And to help you remember, I made this** *(show legend).*

It says what I just told you. See, it says that the RED DOTS *(point)* **on the map will tell you where to find the YELLOW RUBBER DUCK stickers** *(point)*, **and that the YELLOW DOTS on the map** *(point)* **will tell you where to find the RED LADY BUG stickers** *(point)*.

Check Question

Remember, you said that you want to look for the LADY BUG/RUBBER DUCK stickers *(point to appropriate sticker and maintain point)* **So, are you going to look for the LADY BUG/RUBBER DUCK stickers where the RED DOTS are on the map or where the YELLOW DOTS are on the map?**

Trial One __________

If correct	**That's right, in this game the RED DOTS** *(point)* **tell you where the RUBBER DUCK stickers** *(point)* **are hidden in the room and the YELLOW DOTS** *(point)* **tell you where the LADY BUG stickers** *(point)* **are hidden in the room.** *(continue to test trials)*
If incorrect	**Remember, in this game the RED DOTS** *(point)* **tell you where the RUBBER DUCK stickers** *(point)* **are hidden in the room and the YELLOW DOTS** *(point)* **tell you where the LADY BUG stickers** *(point)* **are hidden in the room.**

Appendix H Continued

Symbol Task – Colour-Conflict Version Protocol

Version B – Colour-Conflict **Kitchen**

You are looking for the LADY BUG/RUBBER DUCK stickers, so are you going to look where the RED DOTS are on the map or where the YELLOW DOTS are on the map?

Trial Two: __________ *(Repeat again if incorrect):* Trial Three: __________

If incorrect after 3rd trial:

Remember, in this game the RED DOTS *(point)* **tell you where the RUBBER DUCK stickers** *(point)* **are hidden in the room and the YELLOW DOTS** *(point)* **tell you where the LADY BUG stickers** *(point)* **are hidden in the room.** [*continue to test trials*]

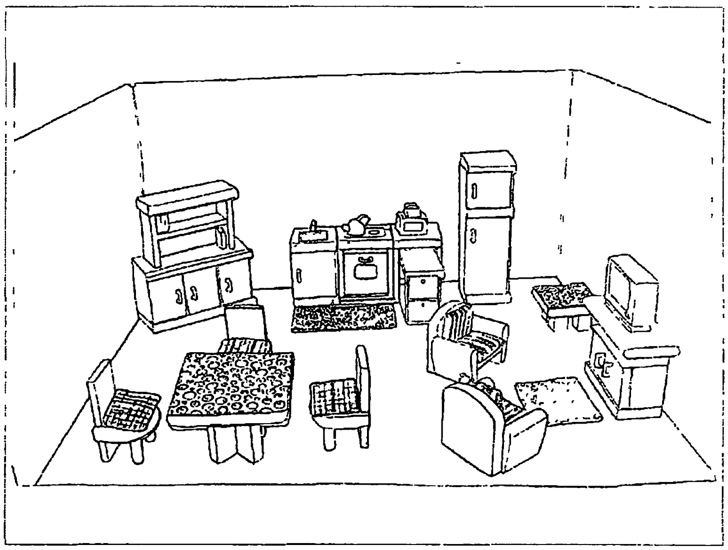
We'll leave this here *(place legend to side)* **to help us remember all that.**

Test Trials

Okay, now I'm going to show you some more maps and you will point to where the LADY BUG/RUBBER DUCK sticker is hidden in the room. Remember, we're not going to touch anything in the room until we're done looking at all the maps.

Can you point to where a LADY BUG/RUBBER DUCK sticker is hidden in the room? *(indicate room with open wave)*

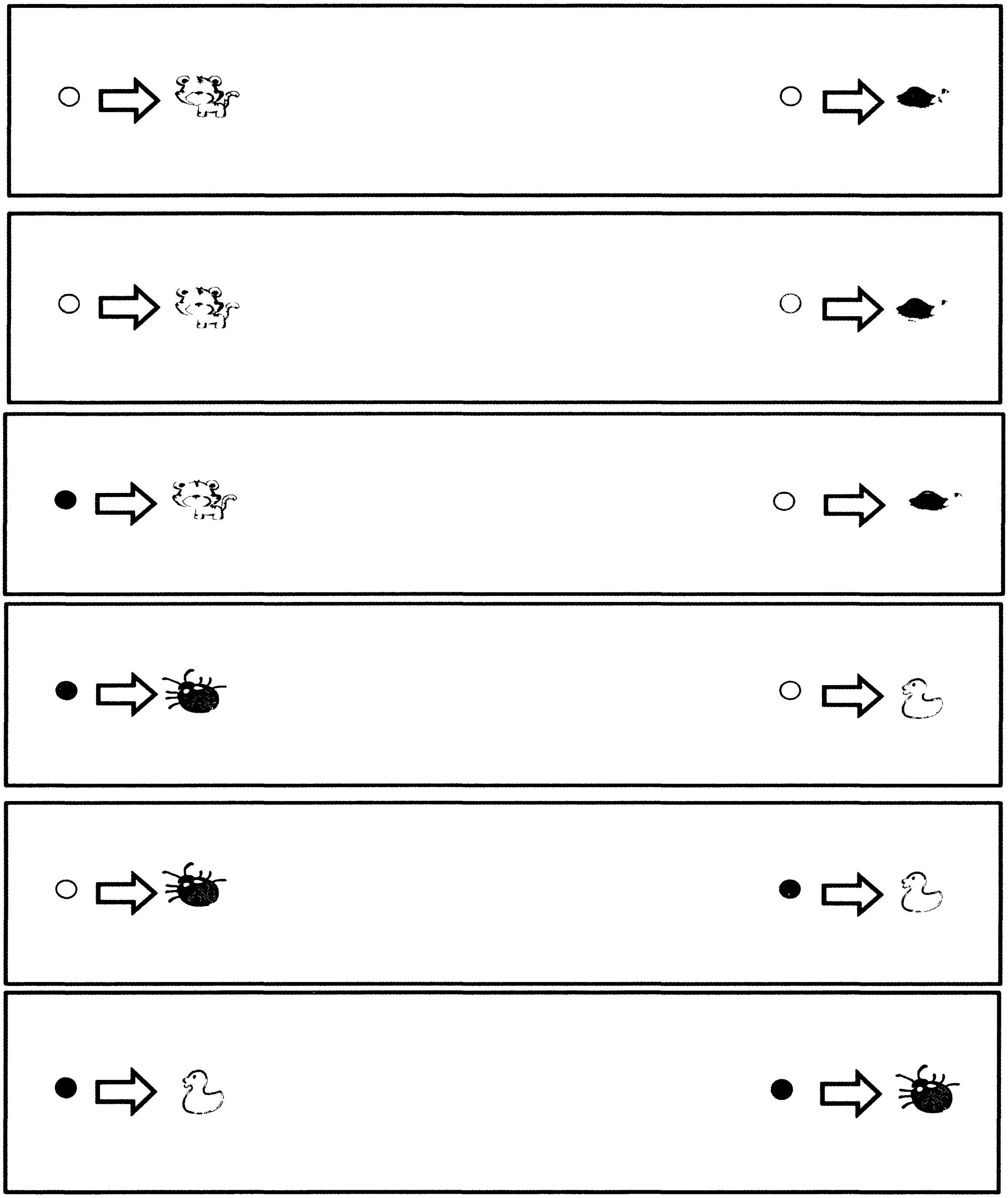
1. __________
2. __________
3. __________
4. __________
5. __________
6. __________
7. __________
8. __________



1 = correct location *2 = alternate location* *3 = incorrect location*
Children are allowed to self-correct
Mark any incorrect locations (3) on the map.

Appendix I

Symbol Task Legends



Appendix J

Forward Digit Span Protocol

Forward Digit Span

Say one digit per second. Stop when child makes an error on both strings of the same length (e.g., when <u>both</u> items 5 <u>and</u> 6 are incorrect) Provide no feedback after 2 training trials

I'm going to say some numbers, and I want you to say them back to me the same way I say them to you. Do you understand? Let's try one. Ready? Listen carefully: 2 – 4 *(score below)*

Let's try another one now 7 – 1 *(score below)*

I **2 – 4 (That's right!** *or correct the mistake*) ____ – ____ ; ____ – ____

II. **7 – 1 (That's right!** *or correct the mistake*) ____ – ____ ; ____ – ____

---

1. **6 – 3** ____ – ____
2. **4 – 9** ____ – ____
3. **2 – 9 – 5** ____ – ____ – ____
4. **8 – 1 – 6** ____ – ____ – ____
5. **8 – 5 – 2 – 6** ____ – ____ – ____ – ____
6. **4 – 9 – 3 – 7** ____ – ____ – ____ – ____
7. **8 – 1 – 3 – 7 – 9** ____ – ____ – ____ – ____ – ____
8. **4 – 2 – 5 – 8 – 1** ____ – ____ – ____ – ____ – ____
9. **9 – 3 – 5 – 1 – 8 – 4** ____ – ____ – ____ – ____ – ____ – ____
10. **6 – 5 – 8 – 4 – 2 – 7** ____ – ____ – ____ – ____ – ____ – ____

Children are allowed to self-correct

If child seems stressed after complete trials go back and do a few easy ones (don't score)

Appendix K

Counting and Labeling Protocol

Counting and Labeling

Now I'm going to show you some itty-bitty little things.

Set out Tree, Gift, and Cow.

I'm going to name these toys *(point to each toy as mentioned)*:
Tree – Gift – Cow.

Now I'm going to count them: One – Two – Three.

Now I'm going to count and name them at the same time:
One is a tree – Two is a gift – Three is a cow.

Clear away toys.

Now it's your turn!

Set out Cake, Frog and Teddy.

Can you name these toys? *(Correct if problematic – if child uses reasonable name for toy, do not correct)*

Can you count them? *(Correct if needed)*

Now count and name them at the same time. *(Do not correct)*

☐ (√ or x)

Clear away toys.

It's your turn again!

Set out Sheep, Apple and Hand

Can you name these toys? *(Correct if problematic – if child uses reasonable name for toy, do not correct)*

Now can you count them? *(Correct if needed)*

Now count and name them at the same time. *(Do not correct)*

☐ (√ or x)

Children are allowed to self-correct.

If child counts and names before <u>just</u> naming – have them <u>just</u> name, <u>just</u> count and <u>THEN</u> count & name.

Appendix L

Corsi Span Protocol

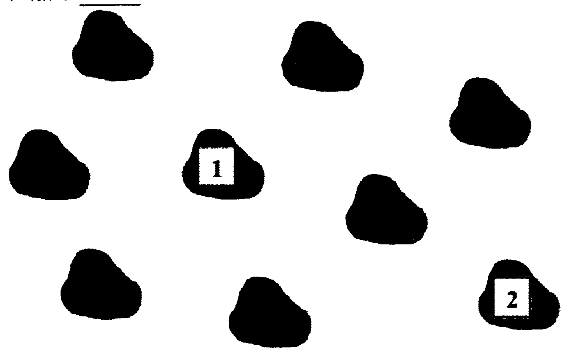
CORSI SPAN

Place page with "lily pads" on table in front of child.
Point to one lily pad per second. Stop when child makes an error on both strings of the same length (e.g., when both items 5 and 6 are incorrect). Provide no feedback after 2 training trials.

See these lily pads? We are going to pretend that our fingers are frogs jumping from lily pad to lily pad. After my frog jumps on the lily pads, you make your frog jump on the same ones in the same order. So watch which ones I jump on, and when I'm done it will be your turn to jump on the lily pads the same way.
Do you understand? Ok, let's try one! Watch carefully.

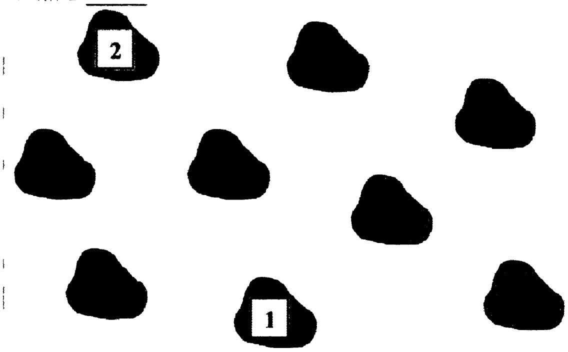
Score below (√ or x).

Trial 1 _____



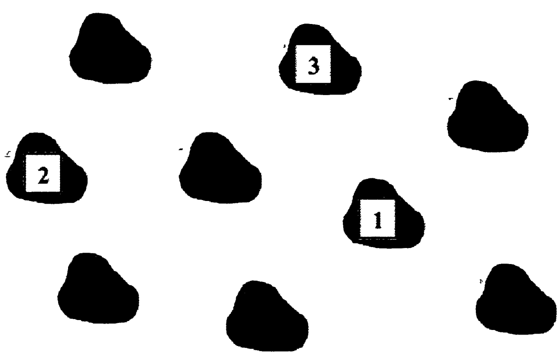
That's right! *or* **Good try! But I pointed to these ones.**

Trial 2 _____

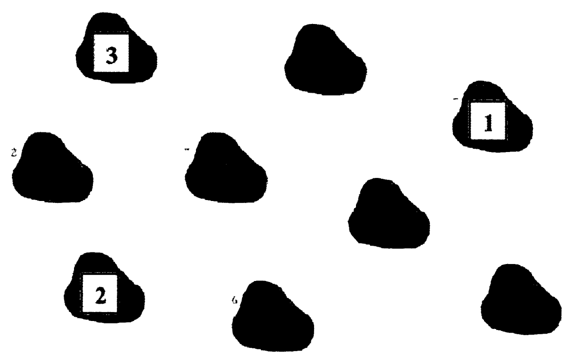


That's right! *or* **Good try! But I pointed to these ones.**

Trial 3 _____

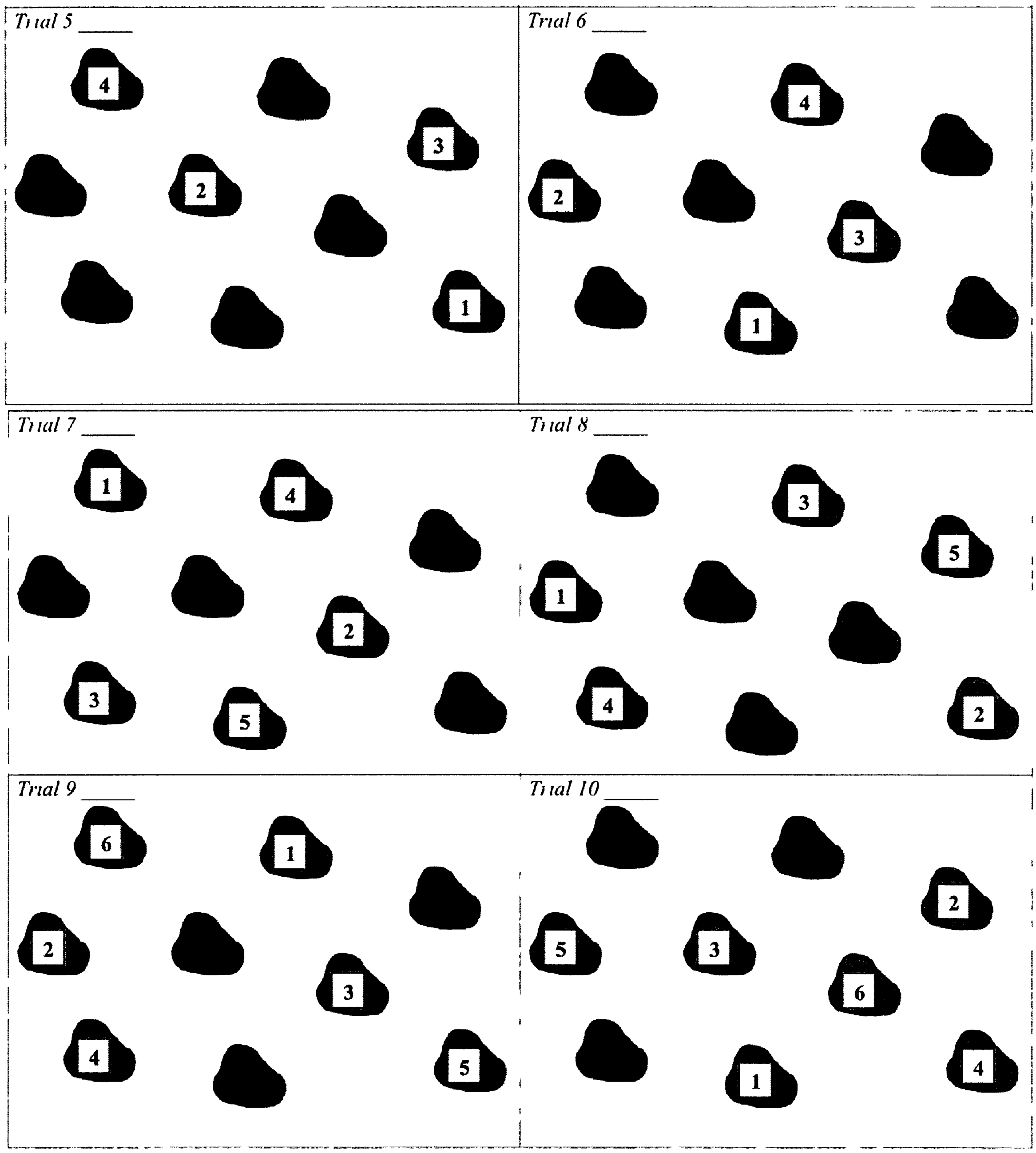


Trial 4 _____



Appendix L Continued

Corsi Span Protocol



Appendix M

Dimensional Change Card Sort (DCCS) Protocol

Standard DCCS – Boats and Rabbits

Present boxes. Show target cards (one at a time) while placing on boxes and saying

Here is a blue boat and here is a red rabbit. This one is blue, and this one is red.

We are going to play a game. This is the colour game. The colour game is different from the shape game. All the blue ones go in this box *(pointing)*, **and all the red ones go in that box** *(pointing)*. **We don't put any blue ones in that box** *(pointing again)*. **No way. We put all the blue ones over here** *(pointing)* **and only red ones go over there** *(pointing)*. **This is the colour game.**

Demo Sort: **Here is a blue one. This one goes here because it's blue.**
Child Sorts: **Here is a red one. Where does this one go?**

Feedback: **Very good** *or* **No, this one's red, so it goes over here.**

Okay, now I'm going to show you some blue ones and red ones.

Show preswitch cards, one at a time:

If it's a blue one, then it goes here. If it's a red one, then it goes there.

Show the card:	**It's a ____ ____ (blue/red one).**	ACCURACY (√ or X)
Give child the card:	**Where does this go?**	☐☐☐☐☐☐☐☐
No Feedback:	**Let's do another one!**	

Okay, now we're going to switch, so I'm going to put my switch cards in now *(put switch cards in)*. **We are not going to play the colour game anymore. We are going to play the shape game. All the boats go in this box** *(pointing)*, **and all the rabbits go in that box** *(pointing)*. **We don't put any boats in that box** *(pointing again)*. **No way. We put all the boats over here** *(point)* **and only rabbits go over there** *(pointing)*. **This is the shape game.**

Show 8 post-switch cards and for each:

If it's a boat, then it goes here. If it's a rabbit, it goes there.

Show the card:	**It's a ____ ____ (boat/rabbit).**	ACCURACY (√ OR X)
Give child the card:	**Where does this go?**	☐☐☐☐☐☐☐☐
No Feedback:	**Okay, let's do another one!**	

Children cannot re-sort once card is in box.

Appendix N

Black/White Stroop Protocol

Black/White Stroop

Now we're going to play a different game!

Show black.

This card is black, right? When you see this card, I don't want you to say 'black'. No, I want you to say 'white'.

Remove black; show white.

This card is white, right? When you see this card, I don't want you to say 'white'. No, I want you to say 'black'.

Training:

Show white. If hesitation - **What do you say for this one?**

[W] [B] (Good.)

Show black. If hesitation - **What do you say for this one?**

[W] (Good.) [B]

number of training trials

If wrong or no response on either trial, repeat rules and training. Max of three training trials – always continue with test trials.

Testing - No feedback:

Circle or write in child's response, if not black/white:

1	W	B	______	8	W	B	______	15	W	B	______
2	W	B	______	9	W	B	______	16	W	B	______
3	W	B	______	10	W	B	______	17	W	B	______
4	W	B	______	11	W	B	______	18	W	B	______
5	W	B	______	12	W	B	______	19	W	B	______
6	W	B	______	13	W	B	______	20	W	B	______
7	W	B	______	14	W	B	______	21	W	B	______

No self-correct : Record first complete response

e.g. : If child says 'Black – no white' code as 'black.' If child says 'Bl--White' code as 'white'.

Appendix O

NEPSY-II Inhibition Task Protocol

NEPSY-II Inhibition Task

- *Strike-out Errors* • *Mark Self-Correct with SC, Missed with M* • *Mark only full responses*

Now we're going to play the name-the-shapes game. I'm going to show you some shapes and you're going to name them for me! Let's try a few first! Use this pointer to follow along, like this *(point to the first few shapes).*

Training Trials: (with feedback)

S	S	C	C	S	C	C	S

Great job! Now let's look at a whole bunch. *Hold page up for child.* **Start naming here and go this way** *(while motioning left to right through rows)* **and use the pointer to follow along.** *Place page in front of child.*

Test Trials: circle final item

S	C	C	C	S	C	S	S
C	S	C	C	S	S	S	S
C	C	S	C	S	C	S	C
S	S	S	C	C	C	C	C
S	C	C	C	S	C	S	S

Completion Time _________ or 180s
Trials Attempted _________ Total Errors ________ [Self-corrected errors _________]

<u>Opposite Game:</u>

Okay, now we're going to play a different game: I'm going to show you those shapes again, but this time you're going to say the opposite. So when you see a square, you're going to say "circle" and when you see a circle you're going to say "square." Let's try a few first!

Training Trials: (with feedback)

If incorect: **Oops! Remember to say the opposite, that is a *square/circle* so you should say *circle/square*. Let's keep going!** *(point).*

If child does not understand, demo the first three: **Watch me: square, square, circle. Now you try!** *(point to first item).*

C	C	S	S	C	S	S	C

Great job! Now let's look at a whole bunch. *Hold page up for child.* **Start naming here and go this way and use the pointer to follow along** *(while motioning left to right through rows).* **Remember to say the opposite.** *Place page in front of child.*

Test Trials: circle final item

C	S	S	S	C	S	C	C
S	C	S	S	C	C	C	C
S	S	C	S	C	S	C	S
C	C	C	S	S	S	S	S
C	S	S	S	C	S	C	C

Completion Time _________ or 240s
Trials Attempted _________ Total Errors ________ [Self-corrected errors _________]

Appendix P

Comparison of Participant Groups

Independent-Samples T-Tests Comparing Groups on Common Variables

	Arbitrary		Conflict				
Variable	*M*	*SD*	*M*	*SD*	*t*	*df*	*p*
Age (in months)	53.45	4.03	53.50	4.25	-0.45	67	.964
Gender	0.55	0.51	0.67	0.48	-1.02	67	.310
Symbol Task Order	1.36	0.49	1.47	0.51	-0.91	67	.369
Match Task Performance	6.88	2.12	7.00	1.79	-0.26	67	.798
Forward Digit Span	2.52	0.84	2.50	0.80	0.08	67	.938
Counting & Labeling	1.12	0.96	1.22	0.93	-0.44	67	.659
Corsi Span	1.53	1.02	1.92	0.89	-1.68	67	.098
DCCS	4.55	3.68	6.33	3.17	-2.15	63.47	.035
Black/White Stroop	12.33	6.70	15.08	6.46	-1.74	67	.087
NEPSY	68.76	30.66	80.80	25.17	-1.79	67	.078
PPVT	58.64	17.75	60.33	26.11	-0.32	61.96	.752

Appendix Q

Examination of Order Effects

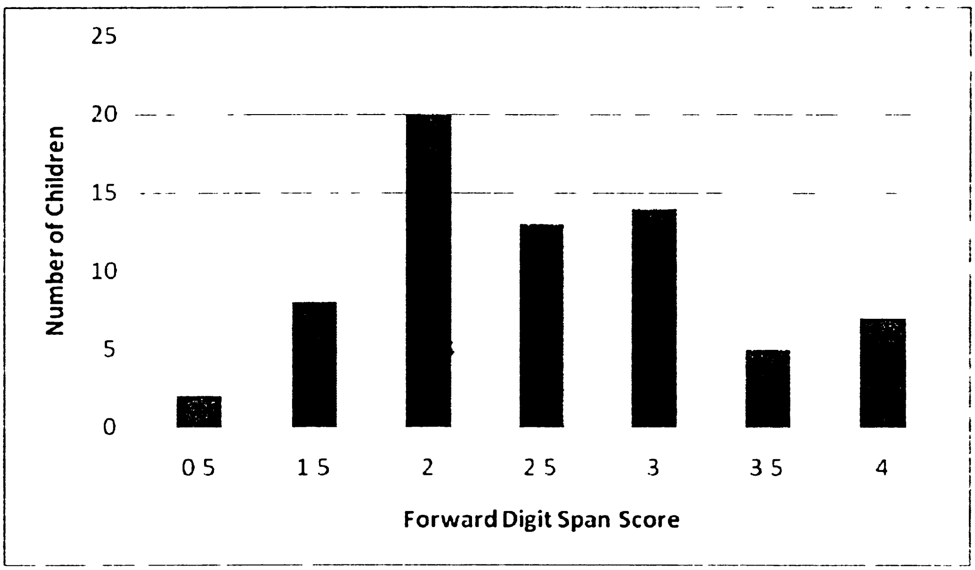
Comparing Symbol Task Performance Based on Task Order

Symbol Task	*t*	*df*	*p*
Matching	-0.07	67	.941
Non-Matching	1.81	40.50	.078

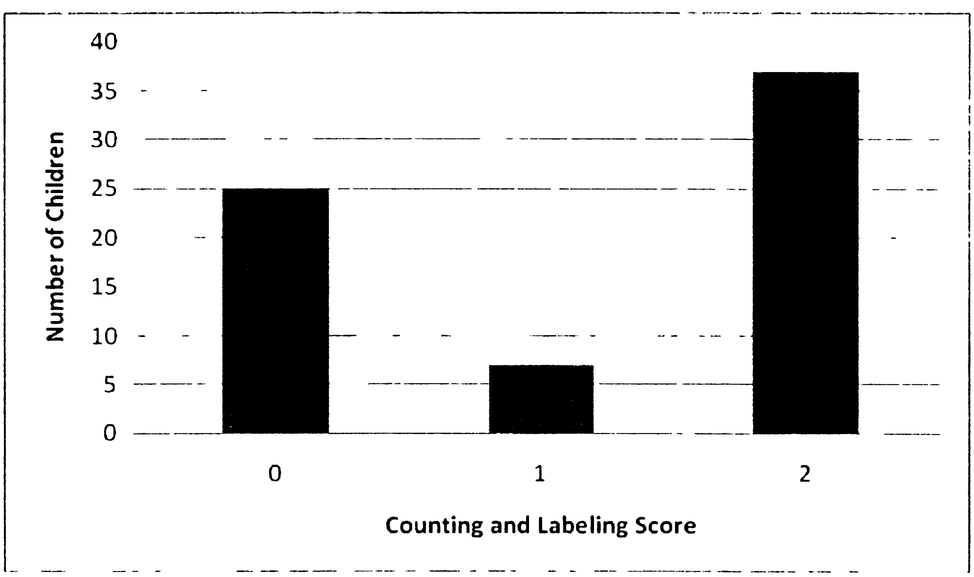
Appendix R

Distributions of Performance for Measures of Memory, Inhibitory Control-Conflict, and Language

Distribution of Performance on Forward Digit Span



Distribution of Performance on Counting and Labeling

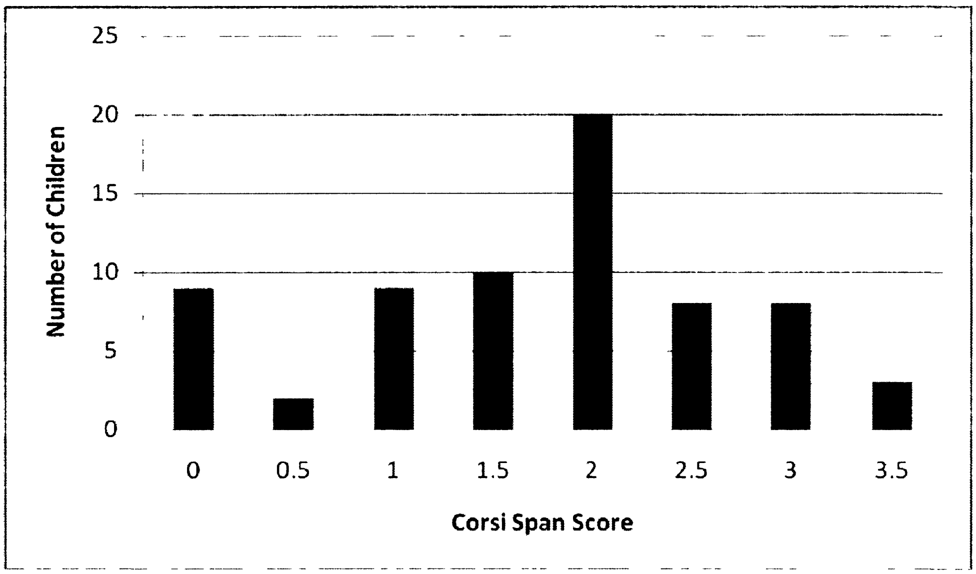


Appendix R Continued

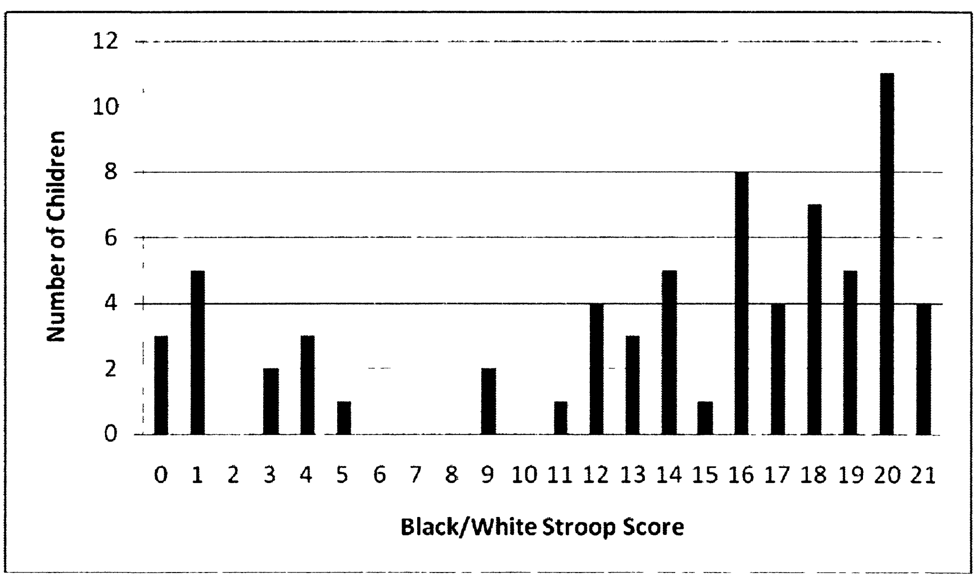
Distributions of Performance for Measures of

Memory, Inhibitory Control-Conflict, and Language

Distribution of Performance on Corsi Span



Distribution of Performance on Black/White Stroop

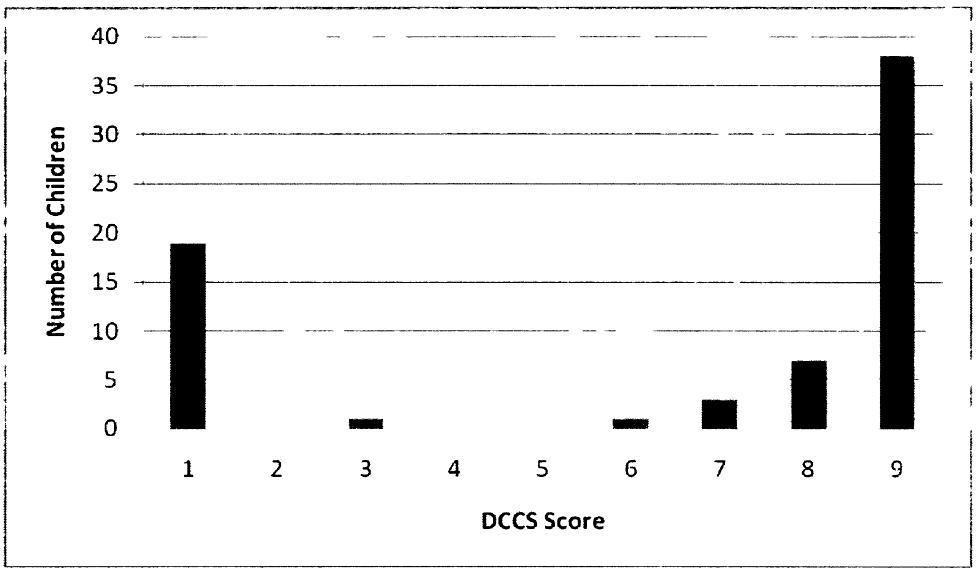


Appendix R Continued

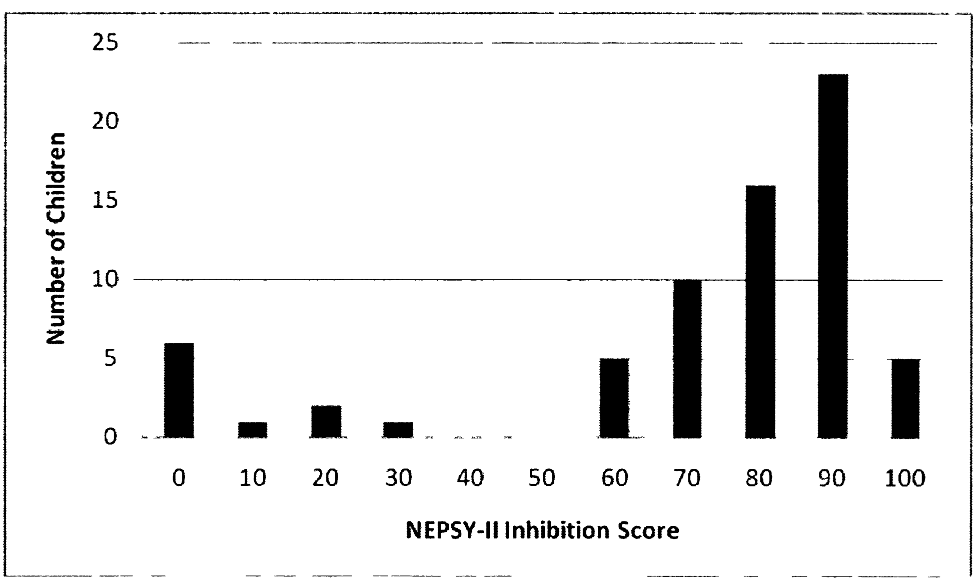
Distributions of Performance for Measures of

Memory, Inhibitory Control-Conflict, and Language

Distribution of Performance on DCCS



Distribution of Performance on NEPSY-II Inhibition Task

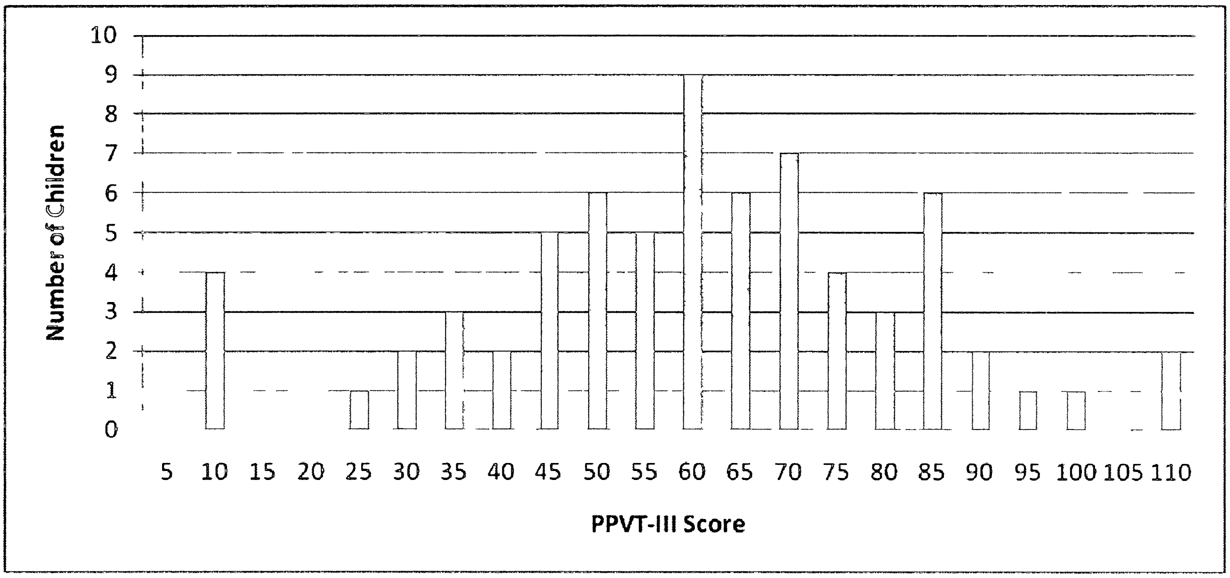


Appendix R Continued

Distributions of Performance for Measures of

Memory, Inhibitory Control-Conflict, and Language

Distribution of Performance on PPVT-III



Appendix S

Normality Statistics for Measures of

Memory, Inhibitory Control-Conflict, and Language

Normality Statistics for Measures of Memory, Inhibitory Control-Conflict, and Language

	Measure	Kolmogorov-Smirnov	Skewness	Kurtosis
Memory	Forward Digit Span	.18*	.03	-.31
	Counting & Labeling	.34*	-.26	-1.94
	Corsi Span	.13	.05	-.65
Inhibitory Control-Conflict	DCCS	.26*	-.37	-1.84
	Black/White Stroop	.20*	-.60	-1.08
	NEPSY Inhibition	.21*	-1.27	.28
Language	PPVT	.08	-.40	.54

Note. * $p < .01$.