MILLER, STEPHANIE E., M.A. Labeling and Representation in a Computerized Multistep Multilocation Search Task with 2.5- to 3-Year-Old Children. (2007)
Directed by Dr. Stuart Marcovitch. 54 pp.

Few studies have examined the development of executive function in children younger than 3 years of age. At this age, language may allow children to reflect upon stronger representations which in turn may influence the control of behavior. The present study was designed to assess the role of differential labeling on an age appropriate variant of the A-not-B task. Sixty-four 2.5- to 3-year-old children participated in a novel computerized version of the mulitstep multilocation search task. On each trial, children were given one of 4 different types of cues to aid search: no cue, visual cue only, experimenter produced label cue, or child generated label cue. Results revealed that children perseverate less only when they generate the label of the hiding location. This is consistent with the HCSM which postulates that generating a label of the hiding location builds a stronger linguistic representation which permits children to reflect abstractly on the representation. In addition, trends suggest that children provided with cues had longer response times, supporting response time as a measure of reflection in young children. Finally, when provided with linguistic information, children who perseverated actually had higher language abilities compared to those who were correct. This result may support the view of linguistic processing as a limited capacity. Those with higher language abilities have the capacity to process linguistic cues and may build a stronger habit on the A-trials making it more difficult for them to override the habitual response on the B-trials.

LABELING AND REPRESENTATION IN A COMPUTERIZED

MULTISTEP MULTILOCATION SEARCH TASK

WITH 2.5- TO 3-YEAR-OLD CHILDREN

by

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A Thesis Submitted to
The Faculty of the Graduate School at
The University of North Carolina at Greensboro
in Partial Fulfillment
of the Requirements for the Degree
Master of Arts

Greensboro
2007

Approved by

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APPROVAL PAGE

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CHAPTER I

INTRODUCTION

Processes involved with more deliberate, calculated action develop throughout childhood. This controlled behavior is thought to be governed by executive function (EF) - cognitive processes that maintain control by monitoring the information one pays attention to and what one does with attended information (Zelazo, Carter, Reznick, & Frye, 1997). According to Zelazo et al., although the action that results from EF may be observable and clearly defined, the processes involved in governing controlled action are not. In this sense, EF in children should be studied as a unitary construct where different processes play a role but can vary with the demands of the task (but see Friedman et al., 2006, for an alternative account).

Zelazo et al. (1997) proposed to study EF from a problem solving framework, where problem solving is the complex activity of EF and the solution to a problem is the observable outcome of EF. In this framework there are four phases to problem solving that the individual must progress through to solve the problem successfully: problem representation, planning of actions, execution of actions, and evaluation of actions. The observable outcome (i.e., the action/behavior in response to the problem) provides an indication as to how EF is operating in the individual. In many of these tasks, individuals must override an incorrect prepotent response that conflicts with the correct response. In this sense, executing the prepotent response is an indication that the individual is not using

EF effectively to control behavior, whereas the correct response indicates that EF is controlling behavior.

The majority of EF work with young children concentrates on the ages between 3 and 5 and approaches EF from this functional problem solving view by presenting age-appropriate variants of adult tasks (e.g., Dimensional Change Card Sort, Zelazo, Frye, & Rapus, 1996; Day-Night Stroop task, Gerstadt, Hong, & Diamond, 1994). For example, the Dimensional Change Card Sort (DCCS) is based on the Wisconsin Card Sort, a common adult EF task associated with frontal lobe damage (Milner, 1963). In the DCCS, children are presented with cards that vary on two dimensions, for example shape (e.g., bunny or car) and color (e.g., blue or red). In the preswitch phase, children are told to sort the cards by one dimension. After the children have successfully sorted the cards for a designated number of trials, they move on to the postswitch phase and are asked to sort the cards by the other dimension. Three-year-old children generally have difficulty sorting by the second dimension, whereas the majority of 5-year-old children successfully sort both dimensions (Zelazo, Müller, Frye, & Marcovitch, 2003). While the work done with 3 to 5 year olds provides us with a better idea of how EF develops within this age range, EF tasks are rarely administered to children younger than 3 years of age because of severe language constraints (but see Carlson, 2005). This is unfortunate as important developments in language and representation that may influence EF are occurring in the second and third years of life. Studies of EF with younger children may help us better understand the role that language plays in EF.

A series of EF tasks for children under three have been developed using variations of Piaget's (1954) A-not-B task (e.g., Diamond, Cruttenden, & Neiderman, 1994; Espy & Kaufmann, 2002; Zelazo, Reznick, & Spinazzola, 1998). In Piaget's experimentations, the infant watched as an object was hidden at one hiding location (location A) and was subsequently allowed to retrieve it. After the object was hidden at location A for a number of times, the infant watched as the object was hidden at a new hiding location (location B) and again was allowed to search for the object. Failure on the A-not-B task occurred when the infant searched perseveratively at location A when the object was actually hidden at location B. Zelazo et al. (1997) suggested that the A-not-B task may tap into EF abilities in younger children because one must override the dominant incorrect response (searching at location A) which competes with the new correct response (searching at location B). In addition, the A-not-B task consists of all the phases of the problem solving process which require EF. Namely the child must: (a) represent the object at the hiding location, (b) choose the hiding location, (c) create a motor plan for retrieving the object, and (d) monitor the search (Zelazo et al., 1997). A perseverative error may be evidence of an immature EF system, specifically with the difficulty in initiating or maintaining conscious control over actions.

Historically, researchers have explained performance on the A-not-B task in a variety of ways. For example, Piaget (1954) determined that success on the A-not-B task signified an advanced understanding of object permanence. Perseveration occurred because infants could not separate the existence of the object at location A from their action of searching for the object. Alternatively, Cummings and Bjork (1983) argued that errors on the task are not perseverative in nature, but are interpreted that way because with only two locations all errors occur at the previous search location. They demonstrated that when more than two search locations were used, children were no more likely to search at the previous hiding location as compared to any other location. However, Diamond et al. (1994) claimed that perseveration indeed occurred when the task has multiple hiding locations. In their experiments, they addressed the fact that Cummings and Bjork drew attention to the correct hiding location by hiding the object at one location, and then covering only that hiding location (i.e., they picked up the lid to the hiding location, hid the object in the location, then replaced only the lid to the hiding location). To assure that search was not due to sustained attention to the last action of the experimenter, Diamond et al. imposed delays and simultaneously lifted and covered all hiding locations. In their experiments, errors did not cluster around the correct location as suggested by Cummings and Bjork (1983). Rather, when more than two locations are available for search, errors occurred towards location A. Diamond et al. interpreted this pattern of search as evidence that both memory and the ability to inhibit the previously correct action jointly influence search behavior.

Perseverative behavior also occurs in a variety of contexts throughout childhood that all share the common feature of pitting an incorrect dominant response against a novel correct response. In a search task where children must use a model of a room to represent a larger room, 2.5-year-old children tend to look for a hidden object in a place that they had retrieved the object previously (O'sullivan, Mitchell & Daehler, 2001). In a more difficult version of the A-not-B task where search space is continuous, 2-year-old children perseverate when searching for toys in a sandbox (Spencer, Smith, & Thelen, 2001). In a similar task, children show a similar perseverative pattern when asked to move a marker to the location where they previously saw a spaceship (Schutte & Spencer, 2002). Finally, in the DCCS, 3-year-old children perseverate and use a familiar rule to sort the same cards when asked to switch to a new rule (Zelazo et al., 2003). The occurrence of perseverative errors in these EF tasks across different ages may suggest that the reason for perseveration in infancy may be the same across the lifespan.

Currently, only two models postulate that the same processes in infancy contribute to perseveration across the lifespan: The Dynamic Field Theory (DFT, Thelen, Schöner, Scheier, & Smith, 2001) and the Hierarchical Competing Systems Model (HCSM, Marcovitch & Zelazo, 1999, 2006). According to DFT, three sources of input interact in an A-not-B type search task to influence where the individual will reach: task input, specific input, and memory input. Task input quantifies consistent, environmental changes in the task or the task parameters (e.g., number of hiding locations, distance between hiding locations, or distinctiveness of hiding locations). Specific input quantifies cues the experimenter gives to the child during the hiding event (e.g., hiding a bright, noisy toy versus lifting a plain lid). Memory input refers to the influence of previous experience in the task, including the history of previous responses. The memory input strengthens after repeated reaches to one location and is the primary reason for perseveration on B trials. According to DFT, perseverative behavior is not exclusive to infancy, but is present across ages as long as the task or specific input makes the task considerably difficult (Thelen et. al., 2001). The DFT explains behavior in a wide range of environments. For example, the DFT was shown to predict behavior accurately when children searched for objects in discrete hiding locations (A-not-B well task, Smith, Thelen, Tizer, &McLin, 1999) and continuous search spaces (A-not-B sandbox task, Schutte, Spencer, & Schöner, 2003; Spencer et al, 2001). In addition, the DFT accurately predicted behavior across delays, different ages (Smith et al., 1999), past reaching experiences, whether or not an object was present (Spencer et al., 2001), and distance between hiding locations (Schutte & Spencer, 2002).

Alternatively, the HCSM (Marcovitch & Zelazo, 1999, 2006) postulates that two systems interact to produce search behavior: a habit based response system and a representational system. The habit based system influences behavior through motor habits formed from the physical action of repeatedly reaching to location A. The representational system influences behavior through the potentially conscious representation of the current location where the object is hidden, and can be strengthened by external sources (e.g., more attractive hiding object, more distinct hiding locations) and internal sources (e.g., reflecting on the representation). On the first B trial, these two systems work in opposition. The motor habit formed toward location A competes with the current representation of where the object is hidden. Behavior is jointly influenced by both systems and perseveration occurs when the representational system fails to override the habit based system.

Although these theories are similar, each provides a different perspective to perseverative behavior across the lifespan. According to the HCSM, the mechanisms behind the changes in perseverative behavior are based in the representational system which map on to several important developments in the child. According to Zelazo and

Zelazo (1998), children develop in their ability to represent and reflect upon stimuli presented to them. For example, if an infant sees an object (e.g., a rattle) they may be able to represent the stimuli at the lowest level of consciousness (i.e., minimal consciousness). The lowest level of representation in minimal consciousness is intentional in the sense that it is about an object and willful in the sense that the representation motivates change or action. For example, the infant may form a representation of a rattle which may trigger a motor response or prepotent action (e.g., shake the rattle). However, while the infant is aware of the object they are representing, they are not aware of the representation and are only governed by reflexive behavior. As the child reaches the end of the first year and can hold two representations at once (e.g., the word ball and image of a round object) behavior becomes more cognitively guided and less reflex-based. With the development of labeling and pointing, objects of minimal consciousness are re-processed and reflected upon making the individual aware of the representation. In addition, more developments occur with further reflection (e.g., self awareness, more sophisticated rule use). In the HCSM, the ability to reflect on representations allows for better performance of behaviors requiring EF. According to this theory, language and symbols may play an important role in guiding behavior.

Language seems to be very closely tied to the development of EF or ability to control behavior. For example, Müller, Zelazo, Hood, Leone, and Rohreh (2004) presented children with an interference control task where they were shown large colored cards with a piece of candy of a different color on the card (e.g., red smartie on a blue card). To receive the piece of candy, children had to choose a small card of the same color of the large card, thereby ignoring the interfering color of the reward. Language was shown to help in the children's ability to control their behavior (i.e., choose the correct small colored card) because when children labeled the correct color of the large card, they choose the correct small colored card more often. However, while language has been shown to help children in many EF tasks, DeLoache (2000) came across an interesting paradox in the use of symbols (e.g., maps, pictures, or models) and the use of language. DeLoache found that symbols are difficult for young children to use even though 2.5-year-olds have progressed toward mastering symbolic systems such as language and participate in symbolic play. She concluded that language develops so early that it may not require dual representation (i.e., the ability to represent a symbol as the physical object itself and the representation of what the symbol stands for). Words may be separate from other symbolic representation systems because they have only one representation, they are synonymous with the object or concept they are representing. In this sense, language may be beginning to form a new representational system in children. Children are beginning to define representations in abstract words and concepts free from the immediate context at hand and use language in their everyday lives to communicate and represent objects to themselves and others. Language changes the way we think; thought becomes represented in terms of words and language (Whorf, 1956).

Luria (1979) was one of the first to explore systematically the development of regulation of behavior through language. In his tasks, he gave children instructions for verbal responses (i.e., when you see a red light say "yes", when you see a green light say "no"), motor responses (i.e., when you see a red light squeeze a bulb, when you see a green light do nothing), and a combination of verbal and motor responses. He found that around 3.5- to 4-years of age, children transition from impulsive responses (e.g., saying no but impulsively squeezing the bulb) to responses controlled by the meaning of an utterance (e.g., saying no and refraining from squeezing the bulb). In a series of more naturalistic observations, Luria presented children with a search task (i.e., a coin was hidden in either a cup or a wine glass) and two types of information: visual (i.e., the children saw where the coin was hidden) and/or verbal (i.e., the children were told where the coin was hidden). Luria found that with age came increased linguistic control. For example, children began to regulate behavior with no visual information based on pure verbal commands and with age they eventually maintained the verbal commands over a delay. Luria also investigated the stability of verbal control of behavior in the search task. In a task similar to the A-not-B task, he found that when an expectation to search in one location was built (i.e., the coin was hidden in the glass 3 or 4 times) if the location was changed (i.e., the coin was hidden in the cup) children who previously searched correctly continued to search in the first hiding location. He interpreted these results as evidence that verbal regulation of behavior was not completely stable.

Other studies of EF have assessed the role of language in controlling behavior. One example of how children benefit from linguistic information is from a study conducted by Homer and Nelson (2005) based on DeLoache’s scale model task. A small object (e.g., little Snoopy) was hidden in the model room and children were told that an identical but larger object (e.g., big Snoopy) was hidden in the same location in the large room. Children who labeled the hiding location were more likely to search correctly than those who did not. Homer and Nelson (2005) suggested that search may have improved in this condition because labeling may change the way children thought about or represented components of the task (e.g., the goal to find big snoopy in the big room or where big snoopy was hiding). Other studies have also shown that language benefits EF performance (Kirkham, Cruess, & Diamond, 2003; Müller et. al., 2004). For example, Kirkham et al. demonstrated that 3-year-old children who labeled the relevant sorting dimension in the DCCS did better than children who did not label. Kirkham et al. proposed that labeling directs the children's attention to the relevant sorting dimension. In addition, labeling may play a role in transforming the components of this task into symbolic thought which may lead to controlling behavior consciously.

There are many reasons why labeling (and other linguistic information) should help EF performance. Zelazo and Zelazo (1998) maintain that labeling is a critical development which enables children to reflect on a representation (cf. Marcovitch & Zelazo, 2006). In addition, Homer and Nelson (2005) suggested that the language system enables cognitive distance which allows one to distance oneself from the immediate physical context and reflect on aspects of the problem or situation abstractly (cf. DeLoache, 2000). However, while these theories suggest that symbols or linguistic labels allow one to create a stronger representation that can influence thoughts and actions, this is highly dependent on the language ability of the child.

Linguistic manipulations do not always benefit younger children. Sophian and Wellman (1983) looked at what type of information children of different ages used in a variation of the A-not-B task. In their task, they provided five different types of A hiding information: (a) visible hiding at A (i.e., children were shown an object hidden at the A location and did not search for the object) (b) finding at A (i.e., children did not see the object hidden at location A and searched until correct) (c) one trial hiding and finding (i.e., children saw the object hidden at A and searched for the object) (d) three trials hiding and finding (i.e., children saw the object hidden at A and searched for the object, this sequence was repeated three times) and (e) location specificity [i.e., locations were rooms in a house; on A-trials the objects were hidden in typical room for the object (e.g., soap in the bathroom) and on B-trials the object was hidden in an atypical room]. When children were provided with visual hiding information on the B trial, 2-year-olds performed equivalent to older 2.5- and 4-year old children. However, when children were provided with a verbal statement of where the object was hidden on the B trial, children of 2 years of age did considerably worse across all types of A hiding information as compared to 2.5- and 4-year-old children. Similarly, Marcovitch and Zelazo (2006) also found that 2-year-old children did not benefit from easily labeled pictures marking the hiding locations on an age-appropriate A-not-B task.

It is possible that young children do not benefit from linguistic manipulations because they do not use language the same way as older children. Vygotsky (1986) proposed a theory on the development of the use of speech. For young children, external speech develops in a social context as a means for communication and is initially separate from abstract semantic meaning out of context. However, the development of speech aids in transforming thought into well-defined parts and ultimately linking thought to speech.

Vygotsky argued that this externalization of speech (speech for others) is the precursor to internal speech (speech for oneself). As internal speech develops, children begin to understand and use language outside of a purely social/communicative context and begin to speak aloud to themselves in an effort to use speech as a tool to solve problems. This use of speech is termed private speech and marks the beginning of children's development of using language to regulate thought which ultimately results in internal speech. Winsler and Naglieri (2003) investigated the developmental pattern of private speech to internal speech in 5- to17-year old children. The occurrence of overt private speech decreased with age while reports of covert internal speech increased lending support to Vygotsky's theory of the transformation from private to internal speech.

According to Vygotsky (1983), children at 2 to 3 years of age are probably using speech primarily in an external social context. However, even in external speech, linguistic information may be used to modulate behavior. In some contexts, the task environment can be conducive to eliciting a linguistic label (e.g., Marcovitch & Zelazo, 2006), or adults can provide the label for the child (e.g., Sophian & Wellman, 1983). Alternatively, children can produce the label themselves (Homer & Nelson, 2005). Based on the work of Zelazo and Zelazo (1998), one may speculate that the self generated pointing and labeling of the child is the foundation of the transformation between external speech to private speech. By forcing the child to produce a linguistic label externally, they may recognize the link between speech and their thought, which may serve to orient themselves to the goals of the task and consciously understand the thought through words. In this sense, younger children may benefit more from self-generated speech than provided speech.

The goal of the present study is to examine the role of labeling in an age appropriate version of the A-not-B task with older 2-year old children who were chosen because they are beginning to benefit from linguistic labels and symbolic representation, and have been shown to benefit from simple linguistic cues (e.g., Sophian & Wellman, 1983). In a computer based version of a multistep multilocation search task (Zelazo, Reznick, & Spinazzola, 1998) children performed a complex action before retrieving the object. The novel computerized version in the present study allowed for the collection of response time in addition to search accuracy. Response time may provide a more sensitive measure of perseveration for several reasons. First, even when correct, slower response times may indicate slower processing or a different measure of perseveration (see Marcovitch & Zelazo, 2006). Second, children who take longer to search may have different patterns of response as compared to children who respond quickly (i.e., children who take longer may be more accurate than children who respond very quickly). If response time is an indication of the amount of time a child spends thinking or reflecting on the problem, this novel measure may provide insight into the processes of reflection.

In the present study, children were assigned to one of four conditions, each depicting a different level of labeling: (a) an unmarked boxes/no label condition in which all hiding locations were marked by identical gray squares, (b) a marked boxes (abstract picture)/no label condition in which abstract pictures which cannot be easily labeled denoted each hiding location, (c) a marked boxes/experimenter label condition in which each hiding location was denoted by an easily labeled picture (e.g., flower, dog) and the experimenter labeled the location, and (d) a marked boxes/child label condition in which the child labeled the hiding location. The unmarked boxes/ no label condition served as a baseline condition in which the children had no linguistic representational cues to mark the hiding location of the object. The marked boxes (abstract picture)/ no label condition served as a comparison condition in which the children had a visual marker for the hiding location (i.e., the different abstract pictures on each box). However, because a label could not easily be made for each picture, it was assumed that children did not create a meaningful linguistic representation for the hiding location. The marked boxes/ experimenter label and marked boxes/ child label conditions served to provide children with different situations in which they could create differential linguistic representations of the hiding location and reflect on this information on the B-trial.

In addition, a measure of language ability, the MacArthur Communicative Development Inventory: Level III/ CDI-III (Fenson et al., 2007), was administered to the parents to provide an index of the children's developing language abilities at this time of study. This scale consisted of three components (i.e., vocabulary, grammar, and everyday use) and provided a measure of language and communicative development with norms established for children between the ages of 30 and 37 months.

Based on the role of language and symbolic representation in the HCSM, it was hypothesized that children in the unmarked boxes condition would exhibit the highest amount of perseveration. Children in the abstract picture/ no label condition may perseverate less due to the opportunity to mark each hiding location visually. Children in the picture/ experimenter label condition may perseverate even less due to the opportunity to create a linguistic representation of the hiding location. And finally, children in the picture/ child label condition should perseverate the least because of the higher probability of creating a linguistic representation of the hiding location. In addition, if response time is thought to be a measure of reflection, then children who were in the conditions with the opportunity to create linguistic representations should have slower response times because of increases in reflection. On the other hand, if response time is a measure of perseveration then children who benefited from linguistic cues should have faster response times. Finally, an interaction was expected between the CDI-III and condition, such that labeling may differentially benefit children depending on their language abilities.

CHAPTER II

METHODS

Participants

A total of 64 children (*M* age= 2.80 years, *SD*= .156) were included in the final sample. Participants were recruited from child care centers and preschools or from a database of parents interested in participating in studies on cognitive development. Twelve children were not included in the final analysis because they did not successfully complete the A-trials (n=10) or due to experimenter error (n=2).

Materials

Measures of the children’s language skills were collected using the MacArthur Communicative Development Inventory: Level III (CDI-III; Fenson et al., 2007). This questionnaire was given to the parents to fill out and included a 100 word checklist of words that the child was using at the time of the visit, samples of 12 sentences that assessed grammatical complexity, and 12 (Yes/No) questions that assessed semantics, pragmatics, and comprehension.

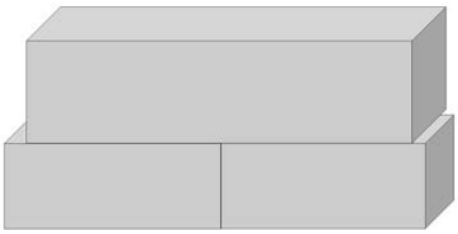
The computerized version of the multistep multilocation search task was programmed using the SuperLab Pro (Version 4.0) software program. Stimuli were presented on a Dell (Latitude, D600) laptop computer with a 14 inch monitor. Children were seated in front of the computer and the stimuli were presented in full screen view. Stimuli were centered on a white background (43.2 x 33 cm). The hiding locations were boxes (7.6 x 6.4 cm) and the object being hidden was a yellow star (4.4 x 3.8 cm). Three blocks were required for the mutistep sequence (see Figure 1): one red block in the bottom left hand corner of the screen (22.9 x 10.8 cm), one yellow block in the bottom right hand corner of the screen (22.9 x 10.8 cm), and one green block centered above the red and green block (39.4 x 12.7 cm). In some conditions, easily identified pictures (dog, flower, car, apple, and pencil) or abstract pictures which were the easily identified pictures scrambled beyond the point of recognition (2.5 x 3.8 cm or 3.8 x 2.5 cm, depending on the orientation of the picture) were centered on the front of each box (see Figure 2). When children made a correct response a pleasant noise sounded (Microsoft Windows Operating System tada.wav). When children made an incorrect response an unpleasant noise sounded (Microsoft Windows Operating System Windows XP Battery Critical.wav). Both accuracy and response times were recorded.

Procedure

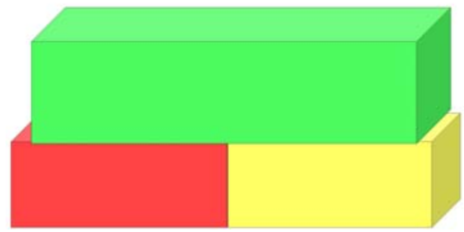
The experiment consisted of three phases: training, A trials, and B trials. In training, the experimenter introduced the multistep procedure to the children by presenting the sequence to the child in a backward training fashion (i.e., presenting the final step first). Children had to complete each step independently (i.e., without experimenter help) before moving to the next step. The training phase began with one unmarked gray box centered on the computer screen against a white background. The lid to the box opened and a yellow star entered the box and the lid closed. Following the hiding of the star, the experimenter asked the children to touch the box on the screen to get the star out. After the children touched the box on the screen, the star appeared and the children heard the

Figure 1. Multistep procedure

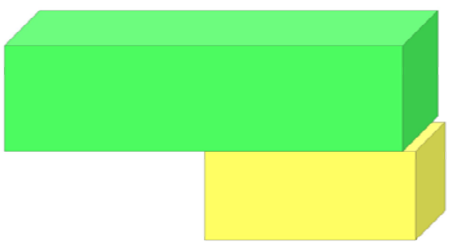
(a) step 1- ten second delay



(b) step 2- remove red block

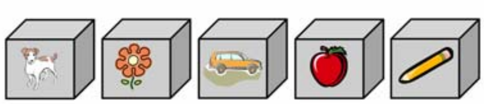


(c) step 3- remove yellow block



(d) step 4- remove green block

(e) step 5- choose hiding location



(f) feedback- correct response

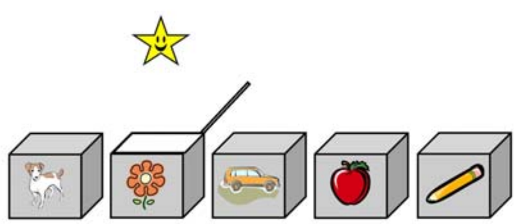
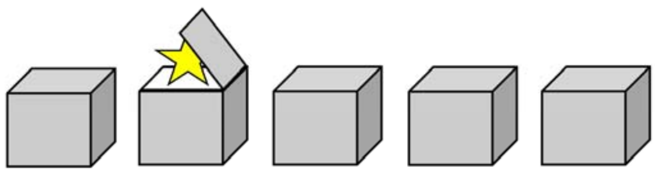
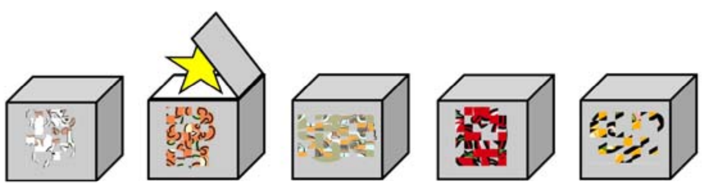


Figure 2. Hiding event

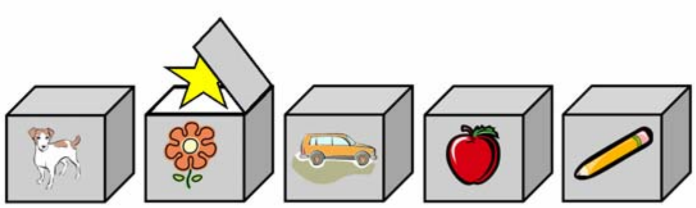
a) (unmarked boxes)



(b) boxes marked with abstract pictures



(c) boxes marked with familiar pictures



reinforcing sound. In the next step, the star entered the same gray box, but after the hiding event a green block appeared on the screen over the gray box. The children touched the green block on the screen to make it disappear and then pressed the gray box to retrieve the star. After the next hiding event, both the green block and the yellow block appeared on the screen. The child first touched the yellow block, then the green block, and finally the box to get the star out. After the next hiding event, the green block, the yellow block, and the new red block appeared on the screen. The children pressed the three blocks in the correct sequence (red block, yellow block, green block) to make each block disappear and the children pressed the gray box to retrieve the star. In the final component of the training phase, the complete multistep procedure was revealed to the children. After the hiding event, three gray blocks appeared on the screen over the gray box. There was a ten second delay in which the children were required to count aloud to five, at which point the blocks changed colors indicating that the children could begin the multistep procedure and search for the star. The children were required to touch the blocks in the correct sequence before they retrieved the star (see Figure 1).

The A and B trials were similar to training trials except five gray boxes were presented on the screen instead of one gray box. The A and B locations were counter-balanced with the stipulation that the B location was on the opposite side of the midline than the A location, and the middle box was never used as a hiding location (see Marcovitch & Zelazo, 2006).

In the unmarked boxes condition, the children were presented with 5 gray unmarked boxes. When the children were ready to begin, the star entered the box at location A (see Figure 2a). After the star had been enclosed inside the box, the experimenter noted where the star was by pointing and saying “The star is in this box”. There was a ten second delay in which the children were asked to count aloud to five, after which they performed the multistep procedure to find the star. Note that the last block pressed (the green block) covered all 5 boxes so the boxes were revealed to the children at the same time (see Diamond et al., 1994). Children were given a sticker if they correctly retrieved the star. The experimenter administered A trials until children correctly retrieved the star on 6 occasions (previous research had shown that perseveration is maximized with 6 trials with 2-year-old children on a non-computerized version of this task, Marcovitch & Zelazo, 2006), followed by the B trials which were administered until one correct B response was obtained.

In the marked boxes (abstract picture)/no label condition, the boxes presented to the children had pictures of objects that could not be easily labeled (see Figure 2b). The procedure was exactly the same as the unmarked box condition, and no attention was drawn to the pictures in this condition.

In the marked boxes/experimenter label condition, the boxes presented to the children had pictures of the easily identified objects on them (see figure 2c). The procedure was the same except in this condition the experimenter labeled the correct location (e.g., “The star is in the apple box”).

In the marked boxes/child label condition, the procedure was the same except the children were asked to label the location (e.g., “Which box is the star in?”). If the children did not answer or named the wrong box, they were told the correct location of the star and instructed to name the box themselves.

CHAPTER III

RESULTS

A-trials

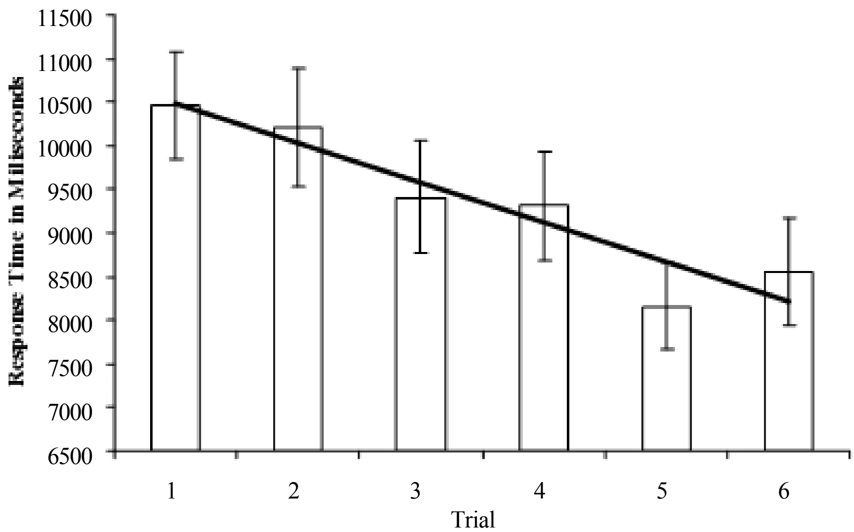
The mean response times on each A trial are presented in Figure 3. An individual growth modeling analysis on response time was conducted using maximum likelihood estimation method to determine if performance improved across A trials. Waves of measurement were represented by trials in this design and there were a total of six trials. Analysis was conducted using a linear level 1 specification shown in Equation 1.

$$\text{Response time}_{ij} = \pi_{0i} + \pi_{1i}\,\text{trial} + \varepsilon_{ij} \quad (1)$$

In Equation 1 response time $_{ij}$ represents the response time of finding the hidden object for child i at time j, π_{0i} represents child i's true initial status or response time at trial 1, and π_{1i} represents child i's true rate of change over trials. The residual in Equation 1 (ε_{ij}) represents the within person random effects or the amount of variance in the accuracy of an individual that is not predicted by trial. The growth model analysis revealed that response time decreases significantly by 451.59 milliseconds per trial, $t(320) = 4.19$, $p<.01$.

Figure 3. Mean (and SE) response time across A trials

Response $time_{ij} = 10478.58 + (-451.587)\ trial + \varepsilon_{ij}$



Effect of condition on reaction time. An individual growth modeling analysis was also conducted on response time with condition as a predictor variable to assess whether the initial status and/or rate of change of the reaction times differed depending on the type of visual and linguistic information children received on A trials. The growth model analysis revealed that there was no significant difference in initial status, all t statistics (116.5) < 1.30, p>.05, nor the rate of change, all t statistics (320) < .67, p>.05, for children in different conditions.

B-trials

Because not all parents returned the CDI-III, analyses of the B-trials were conducted in two phases: (a) without the CDI-III using the full sample and (b) with the

CDI-III using the subsample. Three dependent variables of interest were investigated: exact perseveration, generalized perseveration, and response time. Exact perseveration was defined as search exactly at location A on the first B-trial. Generalized perseveration was defined as search away from location B and toward (and including) location A (see Diamond et al., 1994). Both perseveration measures had a vertical restriction in that search had to be within 3.2 cm above or below the search area (which was equivalent to the height of the search location). Unless otherwise indicated, non-perseverative errors were not included in the analysis. The recording of the response time began when the boxes turned color (indicating the 10 second delay was complete) and was completed when the children selected a hiding location.

No gender differences were found across analyses, nor did gender interact with any other variable. Thus, gender was not considered further in the remaining analyses.

Full Sample Analysis. The proportion of children who exhibited exact perseveration and generalized perseveration are displayed in Table 1. A chi-square analysis did not reveal that the percentage of participants who made an exact perseveration error differed by condition, χ^2 (3) = 3.12, $p>.10$, although the trend suggested that the highest occurrence of perseveration occurred in the unmarked boxes condition, followed by the abstract picture/ no label and picture/ experimenter label condition, and lowest occurrence was in the picture/ child label condition. Planned comparisons revealed a marginally significant difference in the percentage of children who made an exact perseveration error in the unmarked boxes condition and the picture/ child label condition, χ^2 (1) = 2.79, $p<.10$. More children in the unmarked boxes condition exhibited exact perseveration compared to children in the picture/child label condition. A second chi-square did not reveal that the percentage of participants who made a generalized perseveration error differed by condition, χ^2 (3) = 4.11, $p>.10$, although the trend suggested highest rates of perseveration in the unmarked boxes condition, followed by the picture/ experimenter label condition, abstract picture/ no label condition, and lowest rates in the picture/ child label condition. Planned comparisons also revealed a marginally significant difference between the unmarked boxes condition and the picture/ child label condition χ^2 (1) = 3.28, $p<.10$. More children in the unmarked boxes condition exhibited generalized perseveration as compared to children in the picture/ child label condition.

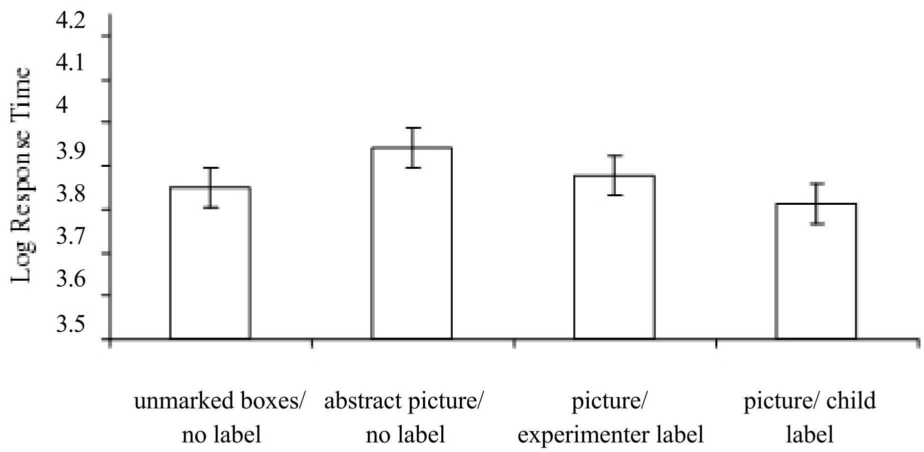
Table 1

Proportion of children who exhibited exact perseveration and generalized perseveration

Condition	Exact perseveration	Generalized Perseveration
Unmarked boxes	.42 (n=12)	.50 (n=14)
Abstract picture/No label	.20 (n=15)	.25 (n=16)
Picture/Experimenter label	.25 (n=12)	.40 (n=15)
Picture/Child label	.13 (n=15)	.19 (n=16)

Due to unequal variances and a positively skewed distribution, response times on the first B trial were subject to a logarithmic transformation. Figure 4 shows the log response times by condition. A one-way ANOVA on response time failed to reveal an effect of condition, $F(3, 59) = .85$, $p > .10$.

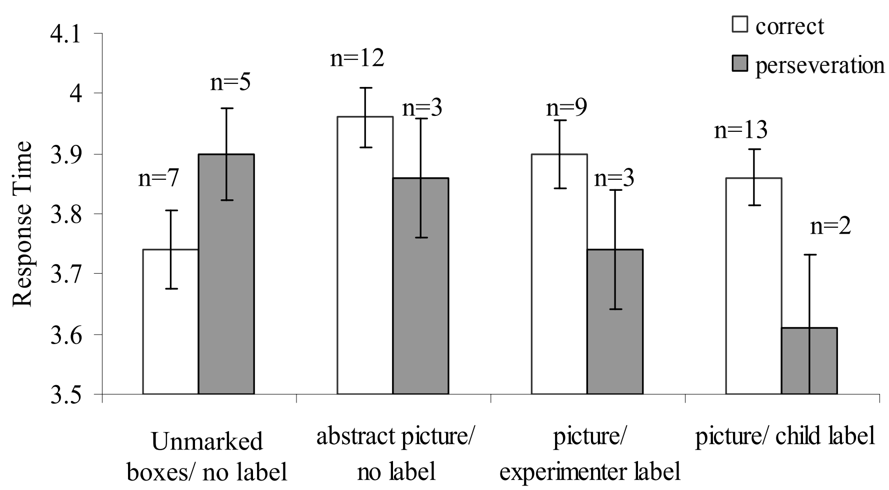
Figure 4. Mean (and SE) log response time by condition



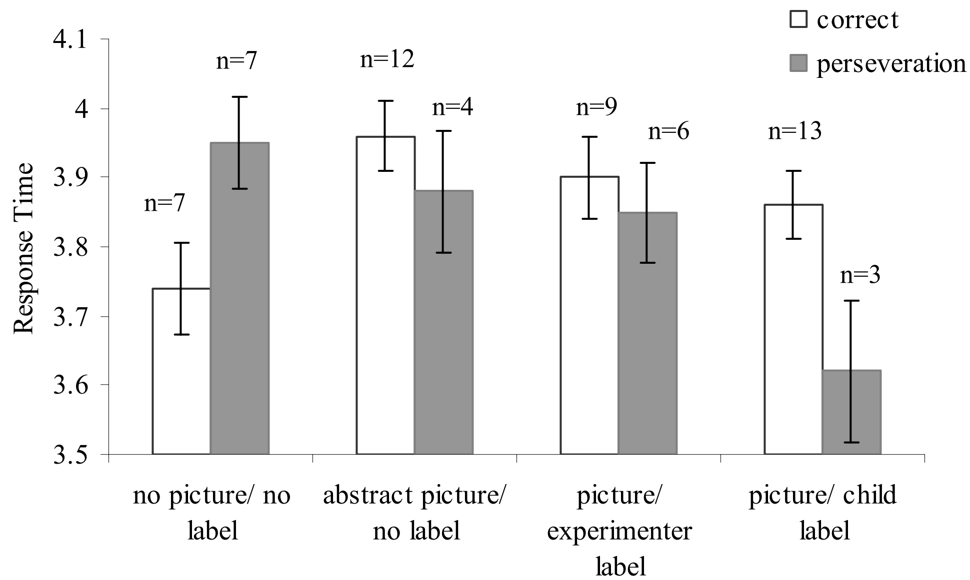
As it was hypothesized that response times may be different for children who perseverate compared to those who answer correctly (e.g., children with longer response times may answer correctly because they are thinking or reflecting on the problem), additional planned comparisons were conducted as speculative measures with response (perseverative or correct) and condition as independent variables. Figure 5 shows the mean response times by condition and response. It was inappropriate to conduct exhaustive planned comparisons and ANOVAS due to limitations in sample size; therefore exploratory analyses were only conducted if the sample size of each cell was greater than 5. Only two analyses met this sample size criterion for exact perseveration. In the unmarked boxes condition, there was no significant difference in log response time between children who were correct and children who perseverated, $t(10)= 1.72$, $p>.10$, although the trend suggested that children who perseverated were slower than children who answered correctly. A one-way ANOVA on correct responses with condition as the independent variable reveled a marginally significant effect of condition, $F (3, 37) = 2.50$, $p<.10$. Post hoc Tukey tests revealed that when children answered correctly, response time was faster in the unmarked boxes condition as compared to the abstract picture/ no label condition ($p<.10$), see Figure 5a.

Figure 5. Mean (and SE) log response time by condition and response

(a) Exact Perseveration



(b) Generalized Perseveration

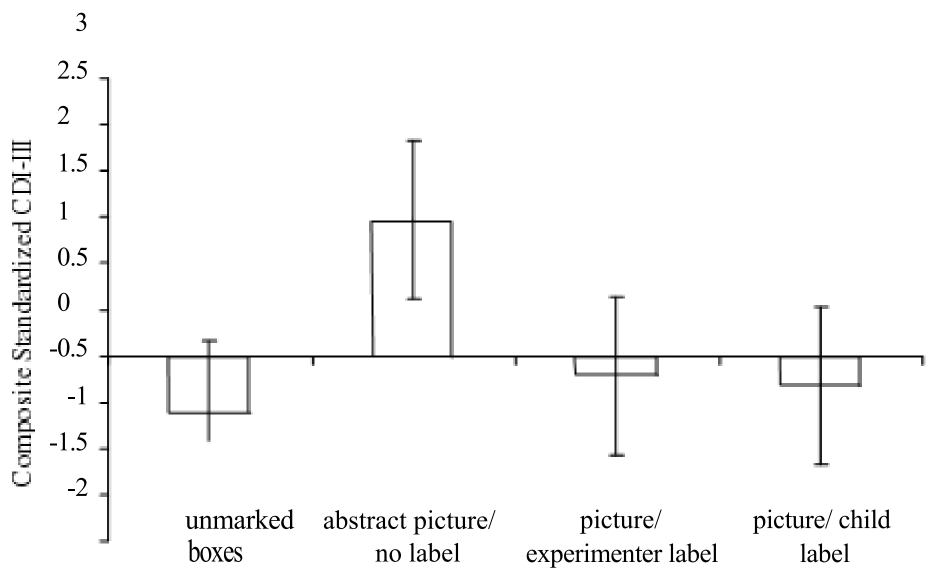


Four analyses met the sample size criterion for generalized perseveration. In the unmarked boxes condition, children who showed a generalized perseveration error had marginally significant slower response times as compared to children who answered correctly, $t(12)= 2.03$, $p<.10$. In the picture/ experimenter label condition, there was no difference between children who showed a generalized perseveration error and children who answered correctly, $t(13)= .76$, $p>.10$. A one-way ANOVA on correct responses with condition as the independent variable and log response time as the dependent variable reveled a marginally significant effect of condition, $F(3, 37) = 2.50$, $p<.10$. Post hoc Tukey tests revealed that when children answered correctly, response time was faster in the unmarked boxes condition as compared to the abstract picture/ no label condition ($p<.10$). In addition, when children perseverated, there was no difference in response time between children who were in the unmarked boxes condition and the picture/

experimenter label condition, t(11)= .92, p>.10, although the trend suggests that children in the picture/ experimenter label condition had faster response times compared to children in the unmarked boxes condition, see Figure 5b.

Analysis with subsample that completed CDI-III. A total of 38 parents and/or guardians returned the CDI-III. There were three components of language ability that the CDI-III measured: expressive vocabulary out of a possible 100 points (M=57.1, SD=23.93), grammar out of a possible 12 points (M=7.79, SD=3.62), and everyday use out of a possible 12 points (M=8.13, SD=2.60). A composite CDI-III score was calculated by transforming each measure into z-scores and then adding the three z-scores together. Mean CDI-III scores by condition are shown in Figure 6. As expected, there were no differences in CDI-III scores across condition, F (3, 37) = 1.28, p>.10.

Figure 6. Mean (and SE) composite standardized CDI-III Scores by condition

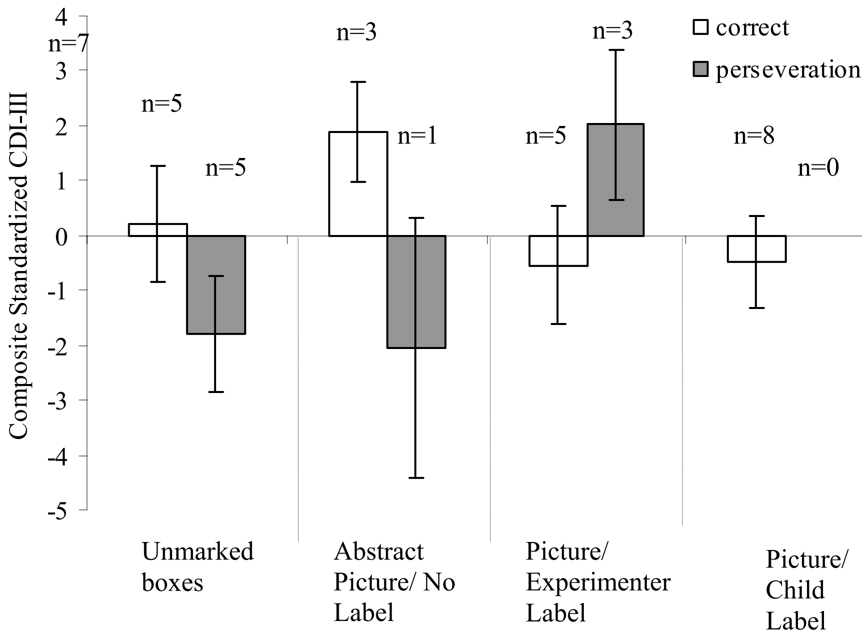


It was hypothesized that CDI-III scores may be different for children who perseverate compared to those who answer correctly. Figure 7 shows the mean CDI-III score by condition and response. ANOVAS and planned comparisons were conducted with response (correct or perseverative) and condition as independent variables. However, it was inappropriate to conduct exhaustive planned comparisons and ANOVAS due to limitations in sample size, therefore once again exploratory analyses were only conducted if the sample size of each cell was greater than 5. Two analyses met the criterion for exact perseveration. For children in the unmarked boxes condition, children who perseverated did not have a significantly different CDI-III score when compared to children who answered correctly, $t(8) = 1.38$, $p>.10$. In addition, when children answered correctly, there was no difference between the conditions in the CDI-III scores, $F(3, 21) = 1.77$, $p>.10$, although trends suggest that correct children in the unmarked boxes and abstract picture/ no label condition had higher CDI-III scores compared to correct children in the picture/ experimenter label and picture/ child label condition, see Figure 7a.

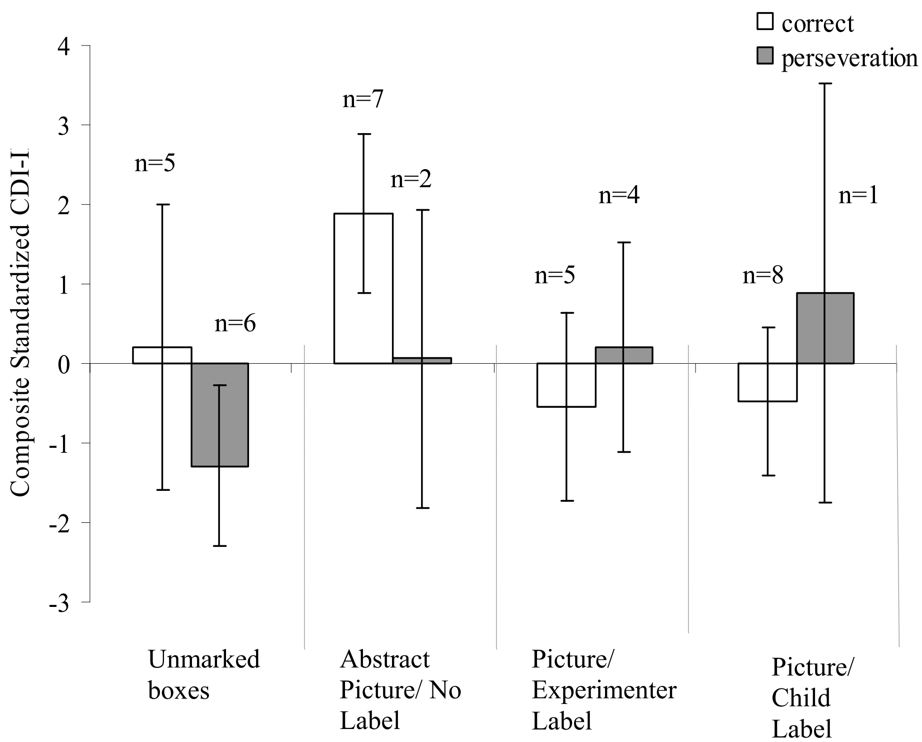
Two analyses also met the power criteria for generalized perseveration. For children in the unmarked boxes condition, children who perseverated did not have a significantly different CDI-III score when compared to children who answered correctly, $t(9) = 1.05$, $p>.10$. In addition, when children answered correctly, there was no difference between the conditions in the CDI-III scores, $F(3, 21) = 1.77$, $p>.10$, although trends were similar to the exact perseveration analysis, see Figure 7b.

Figure 7. Mean (and SE) composite standardized CDI-III scores by condition and response

(a) Exact Perseveration



(b) Generalized Perseveration



CHAPTER IV

DISCUSSION

The purpose of this study was to examine the relation between language cues and EF using a computerized multistep multilocation search task. While studies of EF in older children have established that children in the preschool years benefit from the use of language (e.g., Kirkham et al., 2003; Müller et al., 2004), studies of EF in 2-year-old children are equivocal (Marcovitch & Zelazo, 2006; Sophian & Wellman, 1983). Another objective of the study was to investigate possible associations between language skill and the ability to benefit from label cues.

There are few paradigms designed to study EF with children younger than 3 years of age. One goal of this study was to establish the computerized multistep multilocation search task as an EF measure in 2.5- to 3-year old children. This adaptation of the task met the requirements of an EF task; similar to the A-not-B task, children built a habit to search at A and attempted to override this prepotent response. Results confirmed that children search faster throughout the A trials which suggests that search at location A became more automatic (LaBerge & Samuels, 1974) and therefore prepotent. In addition, perseveration rates in the baseline condition were comparable to other studies of EF (e.g., Zelazo et. al., 1998). This evidence supports the computerized multistep multilocation search task as a valid measure of EF for younger children.

When analyzing responses on B-trials, two different measures of perseveration were assessed: exact perseveration and generalized perseveration. Traditionally, perseverative errors in search tasks with discrete hiding locations occurred exactly at location A (e.g., Piaget, 1954). However, a number of researchers contend that perseveration should also include errors made toward location A (Diamond et al., 1994; Schutte & Spencer, 2002: Spencer, Smith, & Thelen, 2001). Therefore, both measures of perseveration were evaluated. As both measures yielded highly similar results (albeit not always identical), perseveration is discussed in general terms.

The results revealed a trend that children who received no cues had the highest levels of perseveration followed by children who received visual cues and experimenter provided labels, while children who generated labels had the lowest occurrence of perseveration. This trend is consistent with the HCSM in that generating the label produces the highest level of reflection. These results may be interpreted in light of Kirkham et al.'s (2003) theory of attentional inertia, originally formulated to explain performance on the DCCS. According to Kirkham et al., children fail EF tasks because they are not able to redirect attention from the previously relevant aspect of the task or stimuli (i.e., in the present study, searching at location A). Generation of a label may assist children in disengaging from this "attentional inertia" toward location A by allowing for the shift of attention to the relevant hiding location. Kirkham et al. suggest that labeling redirects attention; however, they do not explain how this verbal mediation occurs.

Carlson, Davis, and Leach (2005) may provide an explanation for how verbal and symbolic cues improve performance. In their inhibition based EF task, preschool age children were shown two trays: one displayed two pieces of candy while the other one displayed five. Carlson et al. found that children had difficulty when asked to point to the tray with fewer pieces of candy to receive the tray with more candy. However, they proposed that if children had a symbolic means to represent that candy, they may be able to better inhibit the prepotent response of choosing the tray with more candy. They presented the children with different levels of abstract symbols to represent large amounts of candy (i.e., five pieces of candy, five rocks, many dots, an elephant) and small amounts of candy (i.e., two pieces of candy, two rocks, few dots, and a mouse). Carlson et al. found that children performed better as they received more abstract means to represent the candy. They suggested that symbolic representation improves performance because it allows children to distance themselves from the dominant response which allows for reflection and conscious control over actions (cf. DeLoache, 2000).

Results from the current study are novel in that they demonstrate that labels and symbolic representation improve EF performance in children younger than 3. This is compatible with Zelazo and Zelazo's (1998) theory on the development of representation that postulates that the emergence of labeling and pointing leads to higher levels of representation where children can hold two representations simultaneously (i.e., the *word* and the *object* the word is to represent) and further reflect upon the representation. This recursive processing aids in executive functioning, and is in line with the HCSM's proposal that the ability to reflect on a representation is what guides behavior correctly.

In the context of an EF task, when younger children begin to use labels, they reflect on the correct representation which allows distance from the prepotent response and the redirection of attention to the relevant dimension of the task.

Labeling and language may be the most important type of symbolic representation that children develop because it transforms the way in which individuals think and represent the world (Whorf, 1956). It is interesting that young children at 2.5 years of age are able to benefit from linguistic cues because this may provide insight into how the transformation of thought through language occurs. Vygotsky (1986) maintained that for younger children, speech is external and exists purely in a social context with other people. As children mature, they begin to use speech as a tool and may speak aloud to themselves while working out a problem. This type of speech is termed private speech, and while it is still spoken aloud, Vygotsky viewed this as the precursor to inner speech (i.e., thought through language). In the present study, although generating labels is manifested in an external/social context, it may be more akin to private speech. While private speech is typically found in older children and is self-generated, forcing private speech in young children may be effective because it elucidates the dual nature of the word which allows for reflection.

The finding that children benefit more from producing the label themselves compared to hearing the experimenter producing label is consistent with the HCSM, but not the DFT. The HCSM and DFT make different predictions concerning the use of labels in an A-not-B type task. Although the DFT may be able to account for the improved performance when a label is present on the task (e.g., this may contribute to the effects of specific input as it is a cue the experimenter gives to the child for the hiding location) it does not account for why generating the label should benefit children rather than merely hearing the label. Therefore, the DFT would predict that experimenter produced labels and the child generated labels should improve performance equally. The HCSM, however, does postulate that when children generate the label, they become aware of the dual nature of the stimulus and they can then reflect on the linguistic representation to guide behavior (Zelazo & Zelazo, 1998).

Finally, this finding may also be consistent with the literature on the generation effect (Slamecka & Graf, 1978), the phenomenon usually found in adults that generated material is better remembered compared to presented material. The effort hypothesis (Jacoby, 1978) maintains that generation increases interest which requires more cognitive processing resources. This theory further postulates that the benefits of generation may come into play at the level of the central executive (responsible for the allocation of attention) in the working memory system (Baddeley, 1996). Generated material may recruit more attention, which leads to better processing of the material in working memory. In the current study, children who generate a label for the hiding location on the B trial allocate more attention to the hiding location which is actively processed in working memory.

A unique measure for the A not B task assessed in the current study was response time. Response times are potentially useful for two reasons: (1) they may provide a different and potentially more sensitive measure of perseveration (i.e., slower responses indicate perseveration of behavior that is correct) or (2) they may provide a measure of reflection (i.e., slower response times indicate reflection). Although there was no overall effect of condition on response time, an interesting trend emerged for children who passed the task. Children who received no cues were the fastest, followed by children in both label conditions (experimenter and child produced), while children who received the visual cue were the slowest. This is broadly consistent with response time as a measure of reflection; children who are provided with information to reflect upon (i.e., an experimenter label, child produced label, or visual cue) take longer to respond correctly. Children who correctly answer in the linguistic conditions may be slower because they are reflecting on this additional linguistic information, while children who answer correctly in the abstract picture condition may have the slowest response because of the additional effort needed to reflect on an entity that is distinct but difficult to label.

Further analyses revealed that when children received no visual or label cues, latencies were faster for correct than perseverative responses. Although there was not enough power to analyze this in all the other conditions, the trends suggest that the opposite pattern holds true when you provide children with visual and label cues; children are faster when they perseverate. This is a potentially interesting interaction, suggesting that response time operates in two different ways depending on the type of information available in the EF task. When children have no linguistic or visual information to reflect on, response time may be a measure of perseveration where slower children perseverate. However, when children have information to reflect upon, those who use this information are slower, which results in response time as a measure of reflection.

Language Ability and Language Use

The final goal of the project was to determine whether children's language ability interacted with the labeling cues. As language measures were only collected for a subsample of the children, power was severely limited due to the small sample size. However, there were some interesting trends. When children received no labels, those who answered correctly had higher language abilities compared to those who perseverated. This finding is consistent with the idea that developing language ability may be correlated with other developments (e.g., intelligence) which may be related to EF. Surprisingly, the opposite pattern was true when children received or produced the linguistic label; children who answer correctly had lower language abilities than those who perseverated. If this pattern holds true, this may shed light on 2.5- to 3-year-old children's limited capacity for processing linguistic information. When verbal cues are provided or generated on the A trials, children of low language ability may disregard or shallowly process labels for the location whereas children of high language ability may deeply process this information leading to a stronger habit. On B trials, when children are presented with a different label for the hiding location, children of low language ability may correctly search at location B because they disregard this competing linguistic information or shallowly use the label. However, children who are particularly sensitive to language have difficulty holding and contrasting the label for both the A and B locations. This is broadly consistent with findings from other EF tasks. Zelazo, Reznick, and Piñon (1995) demonstrated that 2-year-olds have difficulty when asked to sort prototypical exemplars into two categories (e.g., cars as something you ride in and drum as something that you make music with). Zelazo et al. showed that while children have category knowledge (e.g., they can tell you that you ride in a car when asked) they have difficulty simultaneously holding and considering two labels or categories and make errors when asked to sort. It is not until 3-years that children can effectively hold in mind and consider two labels concurrently (Zelazo, Muller, Frye, & Marcovitch, 2003).

Limitations and future directions.

While this study provides an initial investigation into the role of language ability in EF, there are limitations and improvements that must be addressed in future studies. Clearly, the largest limitation in this study was the small sample size which limited the analyses. One immediate goal is to increase the sample size and focus on increasing the return rate of the language measure. Another limitation was that the effect of linguistic information on the A trials cannot be determined. In the current study, when children were in a label condition, the label was given or generated for the location on both A and B trials. While this rules out the possibility that children may answer correctly because the label is novel, it is unclear how labeling on A trials affects performance. Even though reaction time was not significantly different in the different conditions, it is possible that labels influence the strength of the habit built toward location A (e.g., adding the label and picture may create a stronger habit because it is more distinct, see Munakata, 1998). In addition, the sensitivity of the task may be limited because responses were dichotomously coded as perseverative or correct. While response time provided additional insight into the diversity of children's response, it is still an imperfect measure.

Additional measures, such as measures of where the child is looking during search, may increase sensitivity in this task.

The HCSM framework can account for many, but not all the current findings. For example, the HCSM proposes that on B trials, a motor based habit system conflicts with the conscious representational system. However, trends from the current study showed that when children received linguistic information, those with high language abilities perseverated. Because children with high language did poorly on B trials, this may suggest these children use both motor and representational information when building the habit across A trials, and this stronger habit may be more difficult to override on B trials. The possibility that habits are different depending on the possible cues available on A trials and the representational capabilities of the children is not currently depicted in the HCSM. The DFT also suggests other factors which may influence reaching behavior on A trials (e.g., number of hiding locations, distinctiveness of hiding locations) that the HCSM may not account for when quantifying the strength of the habit system. Finally, the HCSM does not account for incorrect responses on A trials; in the model the habit of a child who correctly retrieves the object at A six times in a row is quantitatively the same as a child who needs many trials to correctly retrieve the object at A six times (cf. Thelen et al., 2001). It may be advantageous to expand the habit system to incorporate other factors that may influence the habit built from A trials.

In future studies, it may be interesting to further investigate whether generated labels are a form of private speech in the young child. The current study revealed that children perform best when they generate a linguistic cue for the hiding location. The prompted labeling in this task may be viewed as a form of scaffolding or guiding the child to independently use private speech. However, the results do not speak to the issue of whether children at this age can independently use private speech to guide behavior. While Vygotsky suggests that 2.5-year-old children do not use private speech, conditions may be put in place that may make it easier for children to use private speech. For example, in the same task one could have a condition where the boxes are marked with easily labeled pictures and children can be observed or interviewed during the task to determine if they independently generate the label for the location. Response times and perseveration may be compared to determine the differences between children who are asked to generate the label compared to those who independently generate the label. In addition, it would be beneficial to determine if children who are asked to generate labels are more likely to independently use labels to assist them in other EF tasks. To measure this, children in all conditions could be given a similar EF task with an opportunity to use a label. As children even at 12-months of age have been shown to generalize strategies to similar tasks (Chen, Sanchez, & Campbell, 1997), it would be expected that children in the scaffolding condition (i.e., those who generate the label) will be more likely to independently use private speech.

It may also be valuable to further investigate the potential difference in habit built across A trials between children of differing language abilities. Trends from the current study showed that that when children are presented with linguistic information across A trials, children of high language ability perform poorly on B trials while children of low language abilities perform better. Children with high language abilities maybe form stronger habits across A trials because they incorporate the representational information into their habit while children of low language abilities do not use linguistic cues to the same degree. If this is true, when linguistic information is no longer provided on the A trials (i.e., the habit is the same for children of all language abilities) one would expect the results to change. If linguistic information is only provided on B trials, children of higher language ability will no longer have a conflicting representational habit built toward location A, and they should be free use the label on the B trials to reflect upon the representation and guide behavior. On the other hand, children with low language abilities may perform similar to the current study (the habit should be the same because it is hypothesized that children never used the linguistic label in the current study). It is also possible that children of low language abilities may have difficulty using linguistic cues on the B trials to guide their behavior.

The current study may provide a good starting point for the investigation of EF in younger 2.5-year-old children and the role that developing language plays in the control of behavior. By incorporating measures of response time and systematically studying different types of visual and linguistic information that are available in the environment, this study may begin to shed light on the relationship between language and EF in young children.

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