Toddlers Benefit from Labeling on an Executive Function Search Task

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Miller, S.E., & Marcovitch, S. (2011). Toddlers benefit from labeling on an executive function search task. *Journal of Experimental Child Psychology*, *108*(3), 580-592. DOI:10.1016/j.jecp.2010.10.008.

Abstract:
Although labeling improves executive function (EF) performance in children older than 3 (e.g., Kirkham, Cruess, & Diamond, 2003), the results from studies with younger children have been equivocal (e.g., Sophian & Wellman, 1983). In the present study, we assessed performance in a computerized multistep multilocation search task with older 2-year-old children. The correct search location was either: (a) not marked by a familiar picture nor given a distinct label, (b) marked by a familiar picture but not given a distinct label (c) marked by a familiar picture and labeled by the experimenter, or (d) marked by a familiar picture and labeled by the participant. The results revealed that accuracy improved across conditions such that children made fewest errors when they generated the label for the hiding location. These findings support the hierarchical competing systems model (Marcovitch & Zelazo, 2006, 2009) that postulates that improved performance can be explained by more powerful representations that guide search behavior.

Article:
Executive function (EF) refers to the cognitive processes that play a role in conscious control over thought and action (Zelazo, Carter, Reznick, & Frye, 1997). The emergence and development of EF has become a major concentration in cognitive development (for a review see Garon, Bryson, & Smith, 2008), with many theories of EF focusing on children's ability to represent information and use representations to guide behavior (e.g., Marcovitch & Zelazo, 2006, 2009; Munakata, 1998; Zelazo, 2004; Zelazo et al., 1997). This representational ability transforms during the preschool period as children begin to use language and symbols to form internal representations of their external environment (Piaget, 1959; Vygotsky, 1986). Indeed, most studies that assess the benefit of labeling stimuli are conducted with children 3 years of age or older (e.g., Kirkham, Cruess, & Diamond, 2003). In contrast, there have been few studies that have examined linguistic representation and EF in children younger than 3 years of age, and the study of this younger age group is important as considerable improvements in language occur early in life and the foundational abilities of EF may be impacted by verbal mediation (e.g., Luria, 1979). The goal of the current study was to determine whether toddlers under the age of 3 benefit from the labeling of visual cues on an age-appropriate EF task.

The acquisition of language is perhaps one of the most important developments in childhood. Piaget (1959) suggested that the development of language (within a more broad symbolic function) was so powerful that it changed the way children thought (i.e., the shift from the sensorimotor to the preoperational stage). Vygotsky (1986) further argued that early in life children use and understand speech in relation to the external social context (i.e., external speech: speech that must be spoken aloud to others to have meaning). Eventually children learn to speak to themselves (i.e., private speech), which ultimately transitions to inner speech (i.e., covert speech to oneself) used to regulate thought and behavior. Both Vygotsky (1986) and Luria (1979) hypothesized that private and inner speech influence the control individuals have over actions. Further, Luria demonstrated that language initiates the control of behavior in 3.5- to 4-year-old children as they transition from impulsive responses to responses controlled by the meaning of an utterance.

Language and symbols have influenced EF performance in preschoolers as well. For example, Kirkham et al. (2003) demonstrated that 3-year-old children who were asked to label the relevant sorting dimension on the dimensional change card sort (DCCS) did better than children who did not label themselves but heard the experimenter label (but see Müller, Zelazo, Lurye, & Liebermann, 2008). Further, Rattermann and Gentner (1998) reported that in a relational search task in which children had to find a sticker based on the relationship between two objects, 3-year-old children were more likely to retrieve the sticker correctly based on object relationships (e.g., two objects of the same size) when the experimenter labeled the relationship (e.g., told children the sticker was hidden under the baby/small animal). In addition, Müller, Zelazo, Hood, Leone, and Rohrer (2004) found that children labeling the non-dominant correct response improved 3-year-olds' performance in an interference control task. Labeling may be beneficial because it provides distance from the immediate context, encourages abstract representation of the problem (Carlson, Davis, & Leach, 2005; DeLoache, 2000; Homer & Nelson, 2005, 2009; Jacques & Zelazo, 2005), and redirects attention to the relevant aspects of the task (Kirkham et al., 2003).

The limited linguistic ability of children younger than 3 years of age presents challenges to studying the development of EF because of the complexity of the verbal instructions (e.g., Gerstadt, Hong, & Diamond, 1994; Zelazo, Müller, Frye, & Marcovitch 2003). One method for assessing EF in children younger than 3 years of age is through age-appropriate variations of Piaget's (1954) A-not-B task. Participants watch as a desirable object is hidden at one hiding location (location A) and are subsequently allowed to retrieve it. After the object is hidden at location A for a number of times, the object is then hidden conspicuously at a new hiding location (location B). A perseverative error occurs when participants search incorrectly at location A on the B trials. Marcovitch and Zelazo (2009) argued that success on the A-not-B task requires all the components of EF: updating, inhibiting, and shifting (see also Garon et al., 2008; Miyake et al., 2000). To succeed in the A-not-B task, children must inhibit a dominant incorrect response (searching at location A) and update the representation of the hiding location (from location A to location B) to shift search behavior successfully (switch from searching at location A to location B). Perseverative errors may be evidence of a lapse in EF, specifically with difficulty initiating or maintaining conscious control over actions.

The hierarchical competing systems model (HCSM, Marcovitch & Zelazo, 2006, 2009) proposes that two systems interact to produce search behavior: a habit based response system and a representational system. According to this framework, habits are formed through repeated action (e.g., the habit to drive home after work is based on repeated actions). The representational system influences behavior through conscious thought and representation (e.g., to deviate from the habitual drive home for a trip to the grocery store, one needs to plan the change of direction). Furthermore, the representational system can be strengthened by external (e.g., billboard for the grocery store) and internal (e.g., verbally planning the route to the grocery store) sources. In the A-not-B task, the habit and representational systems work in concert on A trials, but in opposition on the first B trial; perseveration occurs when the representational system fails to override the habit system. According to the HCSM, labeling encourages reflection upon the conscious representation, which strengthens the representational system increasing the likelihood that it will determine behavior.

Unlike studies conducted with older children, studies examining EF in children younger than 3 years of age typically do not reveal a consistent benefit from a labeling condition. For example, Sophian and Wellman (1983) found that when children were provided with visual hiding information on B trials, 2-year-olds performed equivalent to older 2.5- and 4-year-old children. However, when children were provided with only a verbal statement of where the object was hidden on the B trial, 2-year-olds did considerably worse compared to 2.5- and 4-year-old children. Similarly, Marcovitch and Zelazo (2006) found that 2-year-old children did not benefit from easily labeled pictures marking hiding locations. In contrast, Homer and Nelson (2009) reported that 2.5- to 3-year-old children who labeled the hiding location in a scale model search task (i.e., a task where children used a smaller scale model to inform search in an identical larger room; DeLoache, 1989) were more likely to search correctly than those who did not, but only when they had previous experience with the task. It may be that children younger than 3 can only benefit from labeling when they label the stimuli actively, as opposed to listening passively to adults labeling the hiding location for them (e.g., Sophian & Wellman, 1983) or merely providing a task environment conducive to eliciting a linguistic label (e.g., Marcovitch & Zelazo, 2006). In other words, 2.5-year-old children might have to generate language in a social context (e.g., Vygotsky, 1986) for linguistic representations to aid in problem representation and provide cognitive distance in an EF task.

This is consistent with Zelazo’s (2004) Levels of Consciousness (LoC) model that postulates that labeling one’s experiences is necessary for young children to develop higher levels of consciousness. Toward the end of the first year of life, children begin to point, which allows them to represent an object and link a semantic memory to current experience. Zelazo and Zelazo (1998) suggested that developments in language (i.e., pointing and labeling) might provide the impetus for the emergence of the first level of consciousness (i.e., recursive consciousness). Labeling enables an additional representation to be held in mind (e.g., the word “ball” along with the image of a round object), which allows for the contents of consciousness to be re-processed and reflected upon. This ability is at the core of the LoC model and is necessary for higher levels of consciousness (e.g., creation of rules and reflection on rule structure) to emerge. The self-generation of a label may be the optimal method to ensure that young children label their current experiences and re-process them at a higher level of consciousness. Further, generation should be especially important to young children who are just beginning to appreciate dual representations through self-initiated pointing and labeling.

The goal of the current study was to assess whether older 2-year-old children can benefit from the labeling of visual cues by examining performance in an age appropriate computerized version of the A-not-B task (i.e., a multistep multilocation search task, Carlson, 2005; Marcovitch & Zelazo, 2006; Zelazo, Reznick, & Spinazzola, 1998). In this task, children watched on a computer screen as a star entered one of five boxes. Following the hiding event, there was a ten-second delay during which three gray blocks occluded the hiding location. Next, children removed the blocks by pressing them in the correct sequence on the screen. Once the last block was removed the hiding locations appeared and children searched for the star by pressing one of the boxes. Children had to find the star correctly six times in location A before the star was moved to location B.

Children were assigned to one of four conditions, ordered by the availability of visual and labeling cues (see Table 1 and Figure 1). In the *no picture* condition, the hiding locations were identical gray boxes with no distinct markers. The experimenter labeled the location unhelpfully by calling it “this” box. In the *no verbal label* condition, a familiar picture (e.g., flower, dog) denoted each hiding location but was not labeled by the experimenter. In the *experimenter verbal label* condition, on all trials the experimenter labeled the picture on the hiding location explicitly. In the *child verbal label* condition, on all trials children were required to label the picture denoting the hiding location. The HCSM predicts improvement incrementally across all conditions with the best performance in the child verbal label condition. Children asked to generate a label are more likely to become aware of its benefit and the potential to label a different hiding location and thus search correctly at location B. Generation of the label should be the most helpful because young children may need to speak aloud in a social context for speech to have meaning (e.g., Vygotsky, 1986).

Table 1: Characteristics of experimental conditions

Condition	Visual cue	Verbal label present	Verbal label generated
No picture			
No verbal label	X		
Experimenter verbal label	X	X	
Child verbal label	X	X	X

METHOD

Participants

One hundred and fifty-three older 2-year-old children participated in this study (*M* age = 33.06 months, *SD* = 1.80, range: 29.4 – 36.6 months, 77 girls). Participants were recruited from childcare centers, preschools, and a database of parents interested in participating in research on cognitive development. The sample was approximately 19% African American, 1.5% American Indian, .5% Asian, and 79% Caucasian, although the parents of 26 children did not provide demographic information. Of the sample that reported income, the majority (71%) reported an average annual income of $60,000 or higher. Age and sex of the participants by condition are presented in Table 2.

Figure 1: The hiding event by condition (and experimenter prompt).

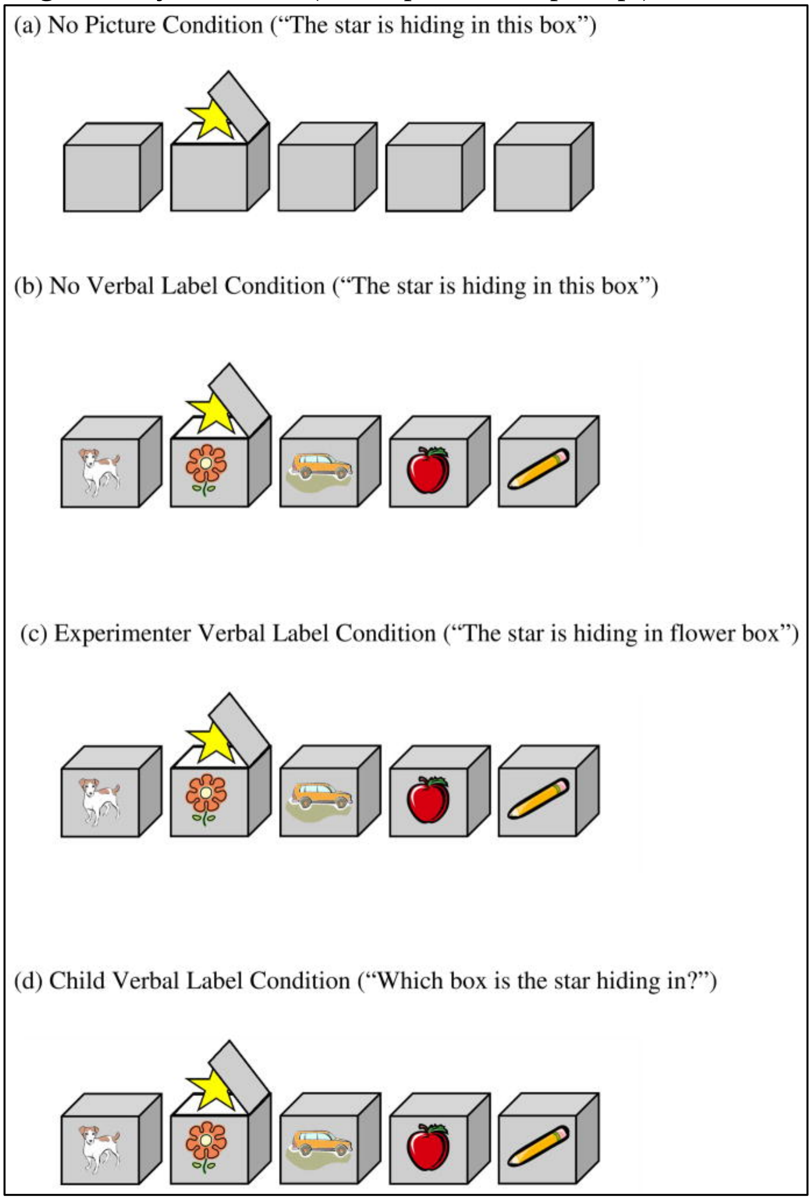


Table 2: Mean age by condition and sex.

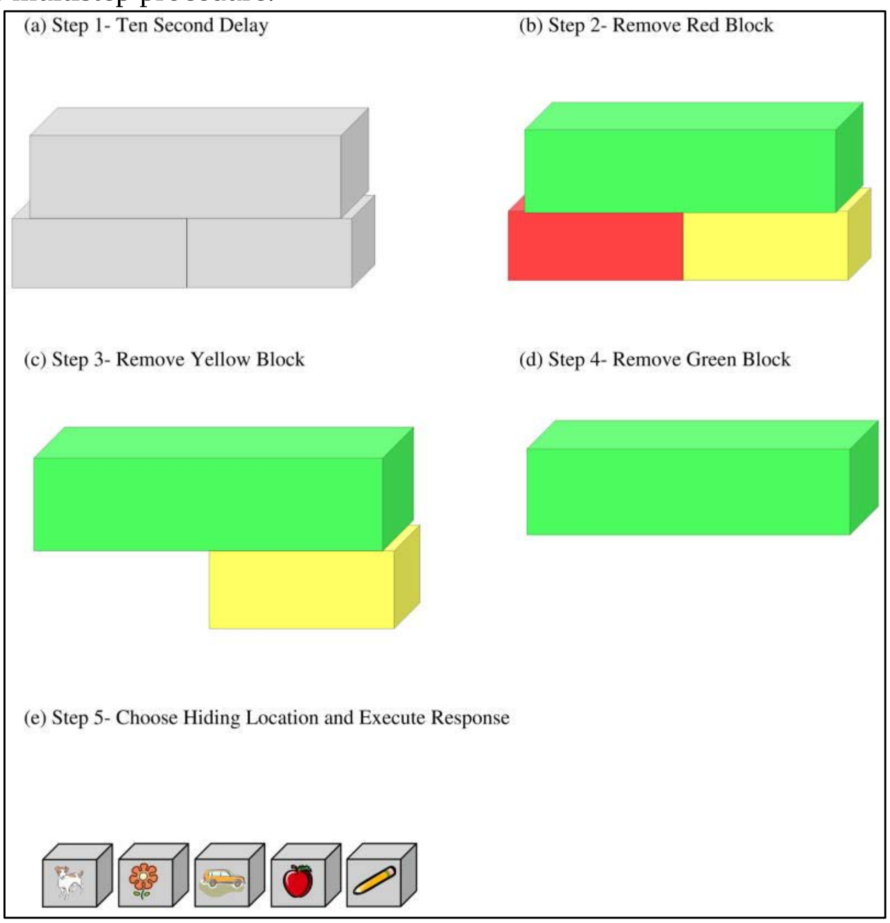
Condition		Age (months)
No picture	Female (*n* = 19)	33.14 (1.59)
	Male (*n* = 19)	33.46 (2.13)
No verbal label	Female (*n* = 19)	32.58 (2.12)
	Male (*n* = 19)	33.40 (1.69)
Experimenter verbal label	Female (*n* = 18)	33.17 (1.66)
	Male (*n* = 20)	32.60 (1.72)
Child verbal label	Female (*n* = 21)	33.77 (1.69)
	Male (*n* = 18)	33.21 (1.79)

Materials

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 laptop computer (Latitude, D600) with a 14-inch monitor and children responded on the Magic Touch touch screen placed directly on the laptop monitor. Children were seated in front of the computer and saw stimuli presented in full screen view centered on a white background (28.5 ×21.6 cm). A yellow star (2.7 ×2.5 cm) entered one of five boxes (4.4 ×4.0 cm) used for hiding locations. In some conditions, easily identified pictures (dog, flower, car, apple, and pencil) were centered on the front of each box (approximate size 2.5 ×2.0 cm; see Figure 1). Children touched the hiding location on the screen to retrieve the star.[1]

Three blocks were required for the mutistep sequence (see Figure 2): one red block in the bottom left hand corner of the screen (12.6 ×5.0 cm), one yellow block in the bottom right hand corner of the screen (13.5 ×5.0 cm), and one green block centered above the red and yellow block (24.6 ×8.0 cm). A pleasant noise (Microsoft Windows Operating System tada.wav) sounded for correct responses and an unpleasant noise (Microsoft Windows Operating System Windows XP Battery Critical.wav) sounded for incorrect responses. Small stickers were used as rewards for correct search.

Figure 2: The multistep procedure.



Procedure

Training. The experimenter introduced the multistep procedure to children by presenting the sequence in a backward training fashion (i.e., presenting the final step first, see Marcovitch & Zelazo, 2006). Pilot work indicated that a delay of 10 seconds and a three part multistep sequence was necessary to make the task difficult enough to elicit perseveration in this age range. Children had to complete the entire training procedure independently (i.e., without experimenter help) before moving on to the testing phase. The training phase began with one unmarked gray box centered on the computer screen (i.e., the eventual middle location) 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 instructed the children to touch the box to find the star. After children touched the box, the star appeared and children heard the 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. 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. Children 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. 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 including the delay was revealed to the children. After the hiding event, three gray blocks appeared on the screen. There was a computer timed ten-second delay in which the experimenter encouraged children to count aloud to 5. After the delay, the blocks changed colors indicating that the children could begin the multistep procedure and search for the star. Children were required to touch the blocks in the correct sequence before they retrieved the star (see Figure 2).

Testing. The A and B trials were similar to training trials except five gray boxes were now presented on the screen during the hiding event. Locations A and B were counter-balanced with the stipulations that location B was on the opposite side of the midline as location A, and that the middle box was never used as a hiding location to minimize interference from the training trials (see Marcovitch & Zelazo, 2006).

Children were randomly assigned to one of four conditions. In the no picture condition, the hiding locations were unmarked. When children were ready to begin, the star entered the box at location A (see Figure 1a). The experimenter noted where the star was by pointing and saying "The star is hiding in this box and you are going to find it right here". There was a ten second delay in which the experimenter encouraged children to count aloud to 5, after which the multistep sequence was performed to find the star. Note that the last block pressed (the green block) covered all 5 boxes so that the boxes were revealed to the children at the same time (see Diamond, Cruttenden, & Neiderman, 1994). Children were given a sticker if they searched correctly. The experimenter administered A trials until children correctly found the star on six occasions (perseveration was most likely after six A trials with 2-year-old children on a non-computerized version of this task, Marcovitch & Zelazo, 2006). After children retrieved the star correctly on the sixth A trial the hiding locations reappeared and children observed the star as it entered a new location (location B). B trials were administered until one correct B response was obtained or until children stopped responding.

The procedure for the no verbal label condition was identical to the no picture condition (i.e., the experimenter pointed to the box and said "The star is hiding in this box and you are going to find it right here"), except the boxes presented to the children had pictures of the easily identified objects on them (see Figure 1b).

In the experimenter verbal label condition, the procedure was identical except that the experimenter labeled the correct location (e.g., “The star is hiding in the apple box and you are going to find it right here”).

In the child verbal label condition, the procedure was the same as the experimenter verbal label condition except children were asked to label the location (e.g., “Which box is the star in? [Child Answer] that’s right and you are going to find it right here”). If children did not answer immediately, they were prompted further (e.g., What is that a picture of? Can you tell me what that is?). If children continued to not respond or named the wrong box, they were told the correct location of the star and were instructed to name the box (this occurred infrequently, n=4, and never on the critical first B trial).[2]

Accuracy and response time were measured on each trial. To encourage precise responding (i.e., location of touch on the touch screen), on training and A trials the location of the touch response had to be exactly within the hiding location boundaries to be counted as correct. On B trials, however, the search area was enlarged to accept touch responses 4.0 cm above or below the search location. The measuring of response time began at the end of the multistep procedure, as soon as the 5 boxes became available for search, and ended when one of the hiding locations was touched.

RESULTS

Outlier Analysis

Response time data were analyzed to determine if there were any outliers on the first B trial response, as extremely low response times may indicate unintentional responses on the touch screen (e.g., if child tapped the last block twice it would be scored as a very fast response time when selecting the boxes) whereas extremely high response times may indicate children were not focused on the task. As response times were positively skewed, they were subjected to a logarithmic transformation (Sheskin, 2004). A box plot analysis on the log response times on the first B trial indicated that seven negative outliers fell below the log response time of 2.645 (Q1-1.5*interquartile range) and one positive outlier fell above log response time of 3.965 (Q3+ 1.5*interquartile range). The 8 cases, which were evenly distributed across conditions, were removed. Measures of skewness and kurtosis on the first B trial were 2.11 and 5.32 before the logarithmic transformation, but improved to .588 and .118 after the transformation and outlier removal. The average age and sex of the participants by condition did not change significantly as a result of the outlier removal.

A trial accuracy

As preliminary analyses did not reveal any main effects nor any interaction with the sex of the participant, the variable was not included in the reporting of any of the analyses.

We analyzed A trial performance because of the possibility that incorrect searches during A trials may weaken the cumulative habit and make perseveration less likely (e.g., Dedrich, Thelen, Smith, & Corbetta, 2000; Thelen, Schöner, Scheier, & Smith, 2001). Table 3 displays the number of errors across A trials. The majority of children (63%) had little difficulty with A trials, as demonstrated by their scores at the lower limit (i.e., scores of 0 or 1 errors). A Kruskal-Wallis test (necessary because of the non-normal distribution of errors) did not reveal a difference in total number of A trial errors by condition, $\chi^2(3) = 2.71$, $p > .05$.

Table 3: Mean number of errors on A trials by condition.

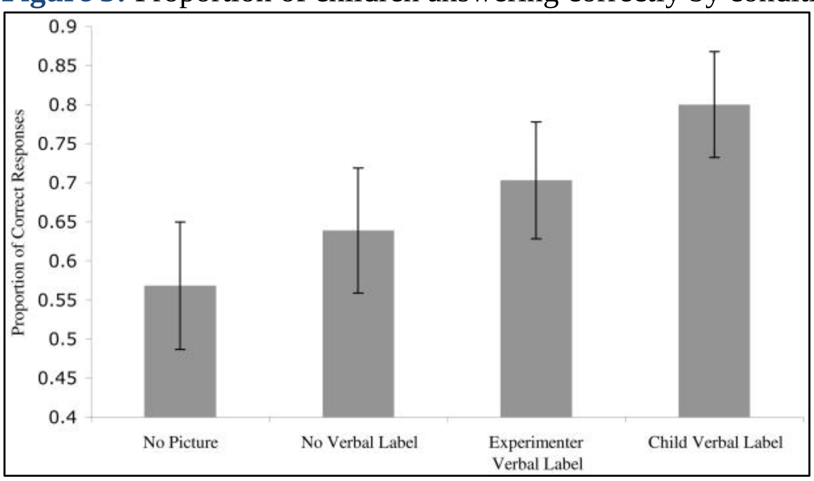
Condition	Number of A trial errors
No picture	1.57 (0.25)
No verbal label	1.00 (0.20)
Experimenter verbal label	1.57 (0.27)
Child verbal label	1.46 (0.24)

Note. Standard errors are in parentheses.

B Trial Accuracy

The primary dependent variable was accuracy on the first B trial (see Figure 3). Notably, 89% of the errors made on the first B trial could be classified as perseverative (defined as search at A or between location A and location B, see Diamond et al., 1994; Marcovitch & Zelazo, 1999; Spencer, Smith, & Thelen, 2001). First, we examined the effect of the visual cue by comparing the *no picture* condition to all other conditions (i.e., *no verbal label, experimenter verbal label*, and *child verbal label)*. Children who received visual cues performed marginally better (71% correct) than children who received indistinct hiding locations (57% correct), $\chi^2(1) = 2.66$, $p \leq .10$, Cramer's $\Phi = .14$. The second analysis examined the effect of labeling by comparing the *no picture and no verbal label* conditions to the *experimenter and child verbal label* conditions. Children who generated or heard labels performed marginally better (75% correct) than children who did not receive the label (60% correct), $\chi^2(1) = 3.59$, $p < .10$, *Cramér's* $\Phi = .16$.[3]

Figure 3: Proportion of children answering correctly by condition.



Finally, we examined whether improvement increased across conditions by utilizing Bartholomew's test for order, intended to assess gradients in proportions across qualitatively ordered samples (Fleiss, Levin, Cho Paik, & Fleiss, 2003). The results support the hypothesis that the proportion of children answering correctly on the B trials follow a prescribed order, namely that the proportion correct increases as the condition provides increases in visual and labeling cues, χ^2 (c1=.50, c2=.49) = 4.78, $p < .05$. In addition, we conducted a test for a linear relationship between the ordered conditions and accuracy with the Mantel-Haenszel chi-square. The significant result provided evidence of this linear relationship, that increases across condition (or increases in visual and label cues) are associated with increase in accuracy, χ^2 (1) = 4.71, $p < .05$.

B Trial Error Run

We defined error run as the number of B trial errors before children searched correctly or withdrew from the task (n=7). Table 4 displays the average error run by condition. A Kruskal-Wallis test, justified by the non-normal distribution on the error run, approached significance, $\chi^2(3) = 7.39$, $p < .10$. Follow-up Mann-Whitney tests comparing error run in the no picture condition revealed a marginal reduction in the experimenter verbal label condition, U (N=74) = 548, $p < .10$, and a significant reduction in the child verbal label condition, U (N=72) = 462.5, $p < .05$.

Table 4: Error run on B trials by condition

Condition	Error run
No picture	2.27 (0.61)
No verbal label	1.08 (0.36)
Experimenter verbal label	0.68 (0.26)
Child verbal label	0.37 (0.18)

Note. Standard errors are in parentheses.

Exclusion of Poor A Trial Performers

As mentioned earlier, incorrect A trial performance may be indicative of off-task behavior or may weaken the habit toward location A and make B trial responses difficult to interpret (e.g., Dedrich et al., 2000; Thelen et al., 2001). We re-analyzed data including only children who committed 0 or 1 A trial errors (n=91). Overall, the analyses revealed similar patterns to the complete sample. First, we examined the effect of the visual cue. The difference in accuracy approached significance with children receiving visual cues performing better (77% correct) than children who searched in the no picture condition (59% correct), $\chi^2(1) = 2.76$, $p \leq .10$, Cramer's $\Phi = .17$. The second analysis examined the effect of labeling with children who had labels present performing better (86% correct) than children who did not receive labeling cues (62% correct), $\chi^2(1) = 6.49$, $p < .05$, *Cramér's* $\Phi = .27$.

Bartholomew's test for order was also conducted. The results support the hypothesis that the proportion of children answering correctly increases as the condition provides increases in visual and labeling cues, χ^2(c1=.44, c2=.52) = 7.13, $p < .05$. In addition, we conducted a test for a linear relationship between the ordered conditions and accuracy with the Mantel-Haenszel chi-square. The significant result provide evidence of this linear relationship, that increases across condition (or increases in visual and label cues) are associated with increase in accuracy, $\chi^2(1) = 6.61$, $p < .05$.

Finally, error run was also analyzed. The error runs were 1.27, 1.11, .18, and .35 for the no picture, no verbal label, experimenter verbal label, and child verbal label respectively. A Kruskal-Wallis test revealed a difference in error run by condition, $\chi^2(3) = 7.98$, $p < .05$. Mann-Whitney tests revealed that children in the verbal label conditions (both child and experimenter) had smaller error runs compared to the no picture condition, both Us (n=44 and 42) < 174, both ps < .05.

DISCUSSION

The current research was designed to assess the influence of differential visual and labeling cues on performance of older 2-year-old children in an EF task. The results indicated improvement as the level of visual and linguistic support increased. Importantly, young children benefited most when the labeling was self-generated.

This ordered improvement across conditions was predicted by the HCSM (Marcovitch & Zelazo, 2006, 2009) that postulated that the addition of visual and verbal label cues increases the likelihood that children will reflect upon the hiding event, which they can later use to guide behavior. It is important to note that improvement in performance cannot be explained by visual and labeling cues encouraging better overall performance on this task, as these additional cues did not influence performance on the A trials. This suggests that there is something specific about labeling that influences the executive component of the task (switching behavior). In addition, it must also be noted that the presence of pictures improved performance (i.e., the *no picture* condition compared to all other conditions). This finding is not surprising, and is in line with research suggesting that distinctive hiding locations improve A-not-B performance (e.g., J. G. Bremner, 1978; A. Bremner & Bryant, 2001; Smith et al., 1999). However, the mere presence of distinct visual cues cannot account for the ordered improvement across conditions.

The superior performance by children who generated a label suggests that simply providing children with a label may not be enough for them to elicit reflection of their current experiences. This finding is consistent with the Vygotskian perspective that young children use and produce language in a social context. Specifically, children may need to generate language to speak to others for it to have representational meaning necessary to guide behavior. Although older children are probably more adept at private and inner speech, younger children may need a more supportive social context (i.e., experimenter prompting) to encourage them to form a linguistic representation of the hiding location. According to the LoC theory (Zelazo & Zelazo, 1998), once a linguistic representation is active, children are able to hold two representations simultaneously (i.e., the *word* and the *object* the word is to represent), which permits further reflection on the representation. Active generation is the first instance that allows children to link their current experience to memory, and at 2.5 years children may need this active experience to form a linguistic representation.

The benefit from self-generated material is also consistent with 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. The current study supports this hypothesis, as children who generated a label for the hiding location on the B trial may have allocated more attention to the hiding location, and because it is actively processed in working memory, this information may be maintained in mind longer and available during the time of search. Following a similar line of reasoning, Kirkham et al. (2003) suggested in the context of the DCCS that generation redirects attention such that a label may assist children in disengaging from the attentional inertia by allowing for the shift of attention to the new relevant information.

However, theories that promote reflection (e.g., HCSM, LoC) differ from attention based theories in the role that labeling plays in the control of behavior. Attention theories do not specifically hypothesize that there is a labeling generation effect per se, in fact, the increase in attention could occur in any modality (e.g., visual, motoric). In contrast, reflection based theories give special credence to linguistic generation, especially early in life when dual representation emerges (Zelazo & Zelazo, 1999).

The benefit of linguistic labels in this task also supports other representational accounts such as Munakata's (1998) active-latent account. From this perspective, flexible thinkers (i.e., those who correctly switch behavior in EF tasks) rely on active representations when representing task relevant information whereas perseverators rely on latent representations. Kharitonova, Chien, Colunga, and Munakata (2009) found that switchers' active representations of task relevant information were more abstract (i.e., they were related to higher order rules and generalized to new stimuli). Therefore, the active-latent account would also predict that the presence of verbal labels should encourage children to use strong active representations (i.e., an abstract verbal label that can be represented separately from the task context) to control behavior.

Although the active-latent account and HCSM both focus on the importance of representations in EF, the HCSM emphasizes the importance of generating a label. In fact, the HCSM speculates that even in conditions where children are not required to explicitly generate a label, it is likely that successful children are generating a label spontaneously (and/or covertly). One possible experimental manipulation that may distinguish the HCSM from the active-latent account is the co-occurrence of an experimenter label with a child generated label.[4] The HCSM predicts that child generated labels would influence behavior equivalently whether or not there was an additional experimenter label. Conversely, the active-latent account would suggest that children are more likely to form a stronger active representation to guide behavior when both the experimenter and the child label the hiding location, and this condition would lead to increased task switching.

Finally, the results from the current study are broadly consistent with the dynamic systems perspective (Spencer & Schutte, 2004; Thelen et. al., 2001), which focuses on how multiple systems (e.g., memory and attention processes) interact with external cues in the task environment to influence the motor plan and behavior of children. Consistent with the trends found in the current study, this theory would hypothesize that visual and labeling cues in the environment improve performance, as it increases the distinctiveness between the A and B locations (Bremner & Bryant, 2001; Smith, Thelen, Titzer, & McLin, 1999). However, the pattern of improvement across conditions and the benefit of generating labels in particular suggest that the presence of visual and labeling cues alone cannot explain performance. From the dynamic systems perspective, labeling an item may serve to differentiate it further from other similar items, but there is no stated reason why self-generated labels should be more useful than experimenter generated labels. In contrast, the HCSM (and the LoC model) do specify how self-generated labels elicit the strongest from of representation.

In conclusion, the present research provides compelling evidence that children younger than 3 can benefit from labeling on EF tasks, and that performance improves with the addition of more visual information and gradations of labeling. From a developmental standpoint, it will be important to determine how children come to generate labels spontaneously (i.e., without external prompting) and use that information to guide themselves seamlessly from one event to another.

ACKNOWLEDGEMENTS

This research was supported by grant 1R03HD054609-01A1 from the Eunice Kennedy Shriver National Institute of Child Health and Human Development. The content is solely the responsibility of the authors and does not necessarily represent the official views of the Eunice Kennedy Shriver National Institute Of Child Health & Human Development or the National Institutes of Health. The authors wish to express their thanks to Jared Cook, Lilly Lawson, Natalie Hellman, Dani Ryan, and Lindsey Waldron for help with data collection and the families who participated in the study.

FOOTNOTES

[1]The majority of children used their finger to respond. Three children, whose responses were not picked up by the touch screen, used a stylus on some trials.

[2]Removal of these four children from the analyses did not reveal any differences in the pattern of performance.

[3]It was possible for children in the no verbal label condition to generate a verbal label spontaneously during the hiding event (e.g., say the star hiding in the dog box). However, this was observed infrequently (n=5), and only one child generated the label on the critical B trial. Removal of these five children did not alter the pattern of performance.

[4]We thank an anonymous reviewer for suggesting the experimental manipulation distinguishing the HCSM from the active-latent account.

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