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The Role of Language in the Development of Cognitive Flexibility

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Abstract

Executive functioning is a fundamental part of everyday life, but develops slowly across childhood. One essential aspect of executive functioning is cognitive flexibility, the ability to update behavior and thought based on the needs of a constantly changing environment. This study investigated the role of language in the development of cognitive flexibility, which has shown contradictory effects in prior work. For example, labels impaired 3-year-olds' cognitive flexibility as measured in an instructed card-sorting task (Yerys & Munakata, 2006), but improved 4-year-olds' cognitive flexibility as measured in an internally-driven card-sorting task (Jacques, Zelazo, Lourenco, & Sutherland, 2007). This study tested whether these opposing findings might be explained by age differences or task differences, by testing 3-year-olds in the Flexible Item Selection Task with and without labels. Children in the condition with explicit labels performed worse than children in the condition with ambiguous labels. These results suggest that explicit labels may impair cognitive flexibility in 3-year-olds, regardless of task, suggesting that age determines whether labels will help or hurt children's cognitive flexibility. Theoretical implications and future directions are discussed.

The role of language in the development of cognitive flexibility

Executive function refers to a complex network of decision-making and behavioral systems that are vital to success in daily life. Aspects of executive function include planning, inhibiting a dominant response, and directing attention (Zelazo, Muller, Frye, & Marcovitch, 2003). Without executive functions, behavior would be based primarily on stored habits, rather than being sensitive to changing circumstances in the environment. Cognitive flexibility, one component of executive functioning, refers to the ability to understand multiple and sometimes conflicting perspectives and representations (Jacques & Zelazo, 2005). One example of cognitive flexibility is the ability to view a common object in an untraditional way in order to maximize its use, such as repurposing an empty jelly jar as a water glass.

Cognitive flexibility emerges slowly across development. Indeed, children are notoriously habit-driven, and often have difficulty breaking routines and flexibly modifying habits and behaviors. However, over the course of development, children slowly gain the ability to adapt behavior to meet the demands of a changing environment. Nonetheless, certain populations continue to face difficulties with cognitive flexibility even as adults, such as individuals with obsessive-compulsive disorder (Chamberlain, Fineberg, Blackwell, Robbins, & Sahakian, 2006), individuals with eating disorders (Tchanturia, et al., 2004), and individuals with depression (Fossati, Ergis, & Allilaire, 2002). Therefore, an improved understanding of the factors that influence cognitive flexibility is not only a central goal for basic science, but also has implications for the domains of education and mental health across the lifespan.

Many frameworks have been proposed to explain the development of cognitive flexibility, with prominent accounts focusing on the role of attention and representational skills (e.g., Kirkham, Cruess, & Diamond, 2003; Zelazo, 2004; Munakata, 1998). One unifying theme across existing frameworks is the idea that competition between habit-based and flexible representational systems can influence the ability to behave adaptively. Language is one factor that has been studied as a mediator between these two systems, due to its well-established role in the representation of abstract concepts (Deak, 2003; Jacques, et al., 2007). The act of interpreting language involves flexible thought in itself, as this requires selection and encoding of specific information in a shifting environment (Deak, 2003). Furthermore, providing a verbal label to an object, idea, or event enables the flexible manipulation of such representations in working memory (Deak, 2003; Cragg & Nation, 2010; Muller, Zelazo, Lurye, & Libermann, 2008), which is especially important for multi-dimensional representations that can be attended to in different ways. Therefore, the role of language in cognitive flexibility has often been studied in children, especially given that both cognitive flexibility and language skills are simultaneously developing.

Labeling is one type of language manipulation that has been employed in cognitive flexibility tasks with children. For example, labeling manipulations have varied the specificity of the label for the first dimension that is presented to children in a sorting task that involves multi-dimensional objects (e.g., from something descriptive, like “these match in color”, to something more ambiguous, like “these match in one way”) before asking children to sort by a second dimension. However, such manipulations have produced contradictory effects. For example, in one study, descriptive labels impaired cognitive flexibility: 3-year-olds who were provided with explicit labels to explain the rules of the Dimensional Change Card Sort task (DCCS; Zelazo, Frye, & Rapus, 1996), a card-sorting cognitive flexibility task, performed worse when asked to later switch to sorting the same cards by a different dimension, relative to 3-year-olds who were instructed using ambiguous labels (Yerys & Munakata, 2006).

In the DCCS, the experimenter provides explicit instructions for how to sort a series of cards (e.g., "In the shape game, trucks go here, and flowers go here") (Yerys & Munakata, 2006). When using ambiguous labels, the experimenter would inexplicitly instruct how the cards were supposed to be sorted (e.g., "In the sorting game, these go here and these go here"). When asked to then switch to another sorting dimension, 3-year-olds performed worse on this task when explicit labels were used. Instructing both ways the participants need to sort the cards makes the DCCS an externally-driven task, because participants are provided with all the necessary to successfully complete the task. One explanation for the performance differences between groups is that when labels are used in externally-driven contexts, activations associated with the first sorting rule are strengthened. This may cause children to fixate on that sorting rule, which could lead to impaired switching when a conflicting sorting rule is externally instructed (Yerys & Munakata, 2006).

In contrast, other studies have found that descriptive labels improve cognitive flexibility: 4-year-olds who were provided with labels to explain the rules of a different cognitive flexibility task, the Flexible Item Selection Task (FIST, see Figure 1; Jacques & Zelazo, 2001) performed better than those given ambiguous labels when asked to sort images in a new way (Jacques et al., 2007). In the FIST, children must select a matching

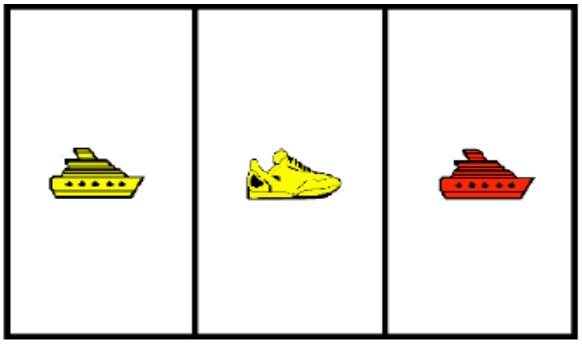

Figure 1. Example stimulus from the Flexible Item Selection Task (FIST; Jacques & Zelazo, 2001). Each card has three images that match on one irrelevant dimension and then two pairs of items that match on unique dimensions. On this card, all the images are the same size. Additionally, the leftmost item and the middle item match uniquely because they are the same color, and the leftmost item and the rightmost item match uniquely because they are the same thing.

pair from multiple sorting dimensions after watching the experimenter make a selection, without explicit instructions from the experimenter (e.g., "These two go together because they are both the same in one way. Can you pick two pictures that go together, but in another way?") (Jacques et al., 2007). In this internally-driven context, where participants are required to decide for themselves which dimension to sort by, labels for the first rule may alert the child to other possible sorting dimensions, which could lead to improved switching by expanding the possible search space.

These contradictory effects of labeling could be explained by two competing interpretations: 1) differences in the type of cognitive flexibility tapped by each of the two tasks, or 2) differences in age between participants. In terms of differences in the type of cognitive flexibility, one possibility is that labels may improve cognitive flexibility only when it is internally-driven, versus externally-driven. Internally driven cognitive flexibility involves making an inductive inference about how to solve a task without being given explicit, dimension-specific instructions (Jacques & Zelazo, 2005). In externally-driven cognitive flexibility, all relevant information to solve the task is provided (Jacques & Zelazo, 2005). Therefore, it is possible that labels aid in performance in an internally-driven versus an externally-driven context.

Alternatively, labels may only improve cognitive flexibility after a certain developmental period. This could be due to developmental increases in the ability to process the labeled dimension and represent it in working memory (Casey, Durston, & Fossella, 2001). Specifically, there are well-established improvements in working memory capacity and updating abilities across the preschool years (Chevalier, Sheffield, Nelson, Clark, Wiebe, & Espy, 2012; Carlson, 2010). In 4-year-olds, perhaps this increased working memory capacity and updating abilities may enable the use of the first labeled dimension to guide the selection of a second dimension due to the ability to maintain multiple rules in working memory and select a correct response. However, in younger children with relatively weaker working memory abilities, increased processing may cause children to get fixated on the labeled dimension. Without the working memory capacity to hold multiple rules in mind, this increased processing would make it more difficult for them to later switch to a new sorting rule, regardless of whether the context is internally-driven versus externally-driven.

The present study tests these competing interpretations by investigating whether labels improve or impair 3-year-olds' cognitive flexibility in the FIST. Since labels hurt 3-year-olds' performance in the DCCS, but helped 4-year-olds' performance in the FIST, this study will cross the prior studies' tasks and age groups by testing 3-year-olds in the FIST with and without labels. If the effect of labels depends on the type of cognitive flexibility, labels should improve 3-year-olds' ability to switch to a second rule in FIST, just how it helped 4-year-olds in the FIST, and in contrast to how labels affected 3-year-olds' performance in the DCCS. If the effect of labels depends on age, labels should impair 3-year-olds ability to switch to a second rule in the FIST, just as it impaired their ability in the DCCS, and in contrast with how it helped 4-year-olds in the FIST.

Method

Participants

Participants were 3-year-olds (*N* = 55; 28 females and 27 males) between 35 months 23 days and 36 months 7 days (*M* = 36.02 months, *SD* = .17), with the restricted age range chosen to match that of Yerys & Munakata (2006). A total of 65 children participated in the experiment, but 10 children were dropped from the final sample, due to fussing out (becoming frustrated and not completing the task) (*N* = 6), failing to comprehend instructions (*N* = 3) and bilingualism (*N* = 1).

Participants were recruited in one of two ways. Most participants were drawn from the participant database that is maintained by the Department of Psychology and Neuroscience at the University of Colorado Boulder (*N* = 56). Parents register their children in the database by responding to an informational letter they receive at the time of their child's birth, and/or by responding to brochures placed in local day care centers and doctors' offices. All children in the participant database who meet eligibility criteria are contacted by phone or email and invited to participate. Children recruited through the participant database were tested in the Cognitive Development Center, and families tested in the Center were paid $5 for travel expenses. Other participants included in this research were recruited from and tested in local preschools/daycare centers (*N = 9*). School directors were contacted to obtain permission to conduct research within their school, and administrators provided a list of eligible students. All eligible students were sent home with an informational letter and consent form inviting them to participate.

Those children whose parents provided written consent for participation, and who also provided verbal assent to the experimenter on the day of testing, were tested in a quiet corner of their classroom or in a nearby administrative office. Parental consent was obtained for all participants. In both locations, children received a small toy for participating.

Design

Participants were counterbalanced in terms of condition (labels or no-labels) and sequence of labeled dimensions (Sequence A or B, which refers to which of two matching pairs the experimenter points out first). This produced four groups: labels A, labels B, no-labels A, and no-labels B. Participants were randomly assigned to groups, balancing for age and gender. All children were tested individually in sessions that lasted approximately 15 minutes. Children were tested by one of two experimenters: a graduate project leader, or an undergraduate research assistant.

Task and Procedures

All participants were tested in the Flexible Item Selection Task (FIST), which consisted of practice and demonstration trials followed by testing trials (Jacques & Zelazo, 2001). The practice and demonstration trials and the FIST involved a series of laminated white cards. Each card depicted three different images separated by a border and measured approximately 29 cm by 19.5 cm. There were a total of 10 practice and demonstration trials, and 15 testing trials. In all conditions, children sat across a table from the experimenter. When children completed the task in the Center, parents sat next to their children for the course of the game. When children completed the task in a preschool/daycare, it was usually under the supervision of a staff member.

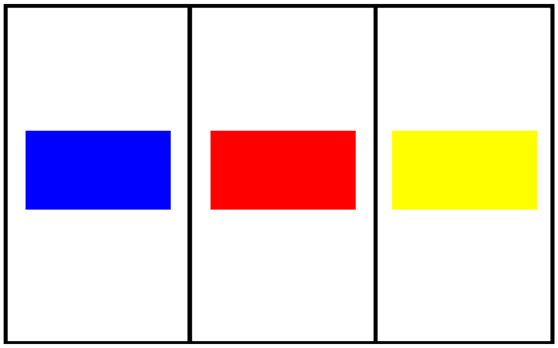

Figure 2. First card of the demonstration/practice trials (Jacques & Zelazo, 2001). Children are asked to point to each color individually. The experiment asked, "Can you point to red?" and then repeated this question for each color. These trials were included to encourage familiarity with colors, shapes and sizes used in the FIST.

First, children were given demonstration and practice trials (see Figure 2). The purpose of these trials was to ensure that children were familiar with the sizes, colors and shapes used in the testing trials, as well as to give children practice with the pointing rules (only pointing to two of three pictures on a card). After becoming familiar with the rules and dimensions, participants viewed one demonstration trial where the experimenter selected two pairs of matching items. Participants then completed two practice trials with feedback. If they selected a pair of pictures that matched on the irrelevant dimension, or did not match on any dimensions, the experimenter would correct them: "You know what? I think that *these* two pictures go together in one way. What do you think?"

After the demonstration and practice trials, 15 testing trials were administered. Test stimuli depicted three objects that varied by three dimensions: size (small, medium, and large), color (red, yellow, and blue), and shape (teapot, boat, and shoe). All testing stimuli had one "irrelevant" dimension, and two "relevant" dimensions. The irrelevant dimension was common across all three objects; for example, all the items could be the same size (such as in Figure 1). Relevant dimensions were common across only two of the three objects; for example, two objects might match by color and two objects might match by shape (such as in Figure 1). Correct performance requires the ability to recognize and sort by both of the two relevant dimensions.

In the testing phase, the experimenter told children, "I think you know how to play my game now, so let's go a little bit faster." Unlike practice trials, in testing trials, the experimenter identified the first pair of matching images ("I'm going to point to two pictures that go together in one way, so I'm going to point to this picture here and this picture here"), and only asked the child to select the second matching pair (as in Jacques et al., 2007). Conditions differed in whether or not the experimenter labeled the matching dimension of the images that she selected before asking children to make their selection. For example, in the labels condition, the experimenter would say, "These two go together because they are both the same size," whereas in the no-labels conditions, the experimenter would say, "These two go together because they are both the same in one way." All children were then asked, "Now can you point to two pictures that go together, but in another way?" No feedback was given during the testing trials.

Results

Conditions were well-balanced in terms of all study variables, and performance on the FIST did not significantly differ between testing locations (Cognitive Development Center or preschool), sequence used (A or B), or experimenter (one of two female experimenters), *ps* > .1. However, there was a marginal effect of gender on FIST, with males performing better ($M = 7.70$, $SD = 3.27$) than females ($M = 6.25$, $SD = 6.25$), $t(53) = 1.75$, $p = .087$, and a significant effect of age, with older children showing better performance (even within the narrow 14-day developmental period during which children were tested), $F(1, 54) = 5.04$, $p = .029$, $R^2 = 0.07$. Therefore, the effect of labels on FIST performance will be considered both with and without controlling for the effects of these additional variables.

Critically, results from an independent samples *t*-test indicate that children in the no-labels condition performed better (M = 7.88, SD = 3.27) on the FIST than children in the labels condition (M = 6.14, SD = 2.84), $t(53) = 2.12$, p = .038, (Figure 3). Scores were out of 15.

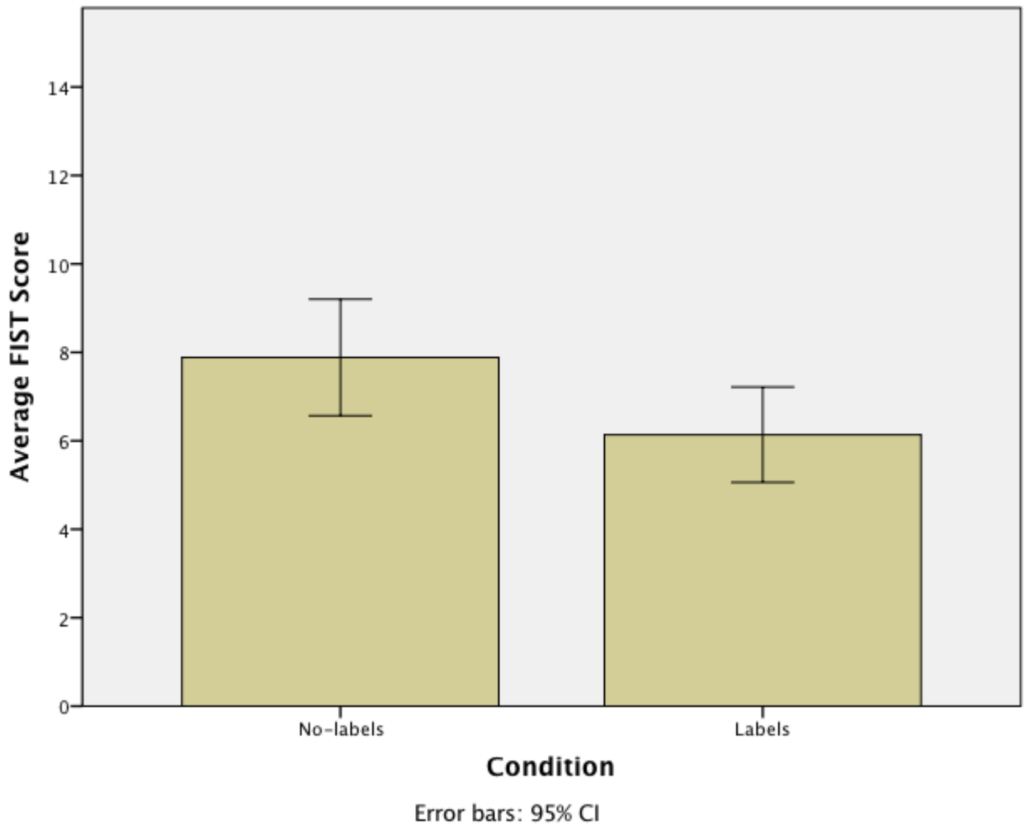

Figure 3. Participants in the no-labels condition performed significantly better than participants in the labels condition, p = .038. This suggests that labeling the first sorting rule in an internally driven cognitive flexibility tasks makes it more difficult for 3-year-olds to switch to a new rule, unlike past research that showed 4-year-olds to do better with labels.

Due to the marginal effect of gender and the significant effect of age, an analysis of variance was conducted to determine the effect of labels on cognitive flexibility after controlling for these variables and their interactions. In the full model predicting FIST scores from condition, age, gender, and their interactions, children in the no-labels condition still performed significantly better than children in the labels condition, F(1,

54) = 4.78, $p = .034$. The effect of age on FIST score was also still significant, $F(1, 54) = 5.40$, $p = .024$, as was the marginal effect of gender, $F(1, 54) = 3.18$, $p = .081$. None of the two-way interactions between gender and condition, age and condition, and gender and age were significant, *ps* > .1. However, there was a significant three way interaction between age, gender, and condition, $F(1, 54) = 4.60$, $p = .037$, such that the effect of age on FIST score was weaker in the labels condition than in the no labels condition, and this was more true for males than for females.

Discussion

The purpose of this experiment was to explore the relationship between language and cognitive flexibility in preschoolers through the use of labeling manipulations. Prior work on this topic has produced contradictory findings: labeling the first dimension of the DCCS impaired cognitive flexibility in 3-year-olds (Yerys & Munakata, 2006), while labeling the first dimension of the FIST improved cognitive flexibility in 4-year-olds (Jacques et al., 2007). The present study tested 3-year-olds in the FIST using a labeling manipulation in order to evaluate competing interpretations of these contradictory findings. Our results point to an age-related interpretation of prior work, in which explicitly labeling the first dimension in a sorting task may impair 3-year-olds' cognitive flexibility, regardless of whether the task is internally or externally-driven.

In addition to the critical effect of labels on cognitive flexibility, some demographic variables also appeared to influence performance. For example, cognitive flexibility improved with age, which was surprising given the narrow age range used. However, some cognitive developments can emerge rapidly, and it is possible that we inadvertently targeted a specific transition period. Another unanticipated finding was the marginal effect of gender, given that gender differences are not consistently found in cognitive flexibility tasks. The effect of these demographic variables will be an important point to explore further in future work.

The difference between 3 and 4-year-olds' ability to effectively use labels to guide flexible thought seemingly points to qualitative differences in cognitive processing between these two ages, indicating the need to extend prominent theories of cognitive flexibility to incorporate these results. Some existing accounts are compatible with the findings that 3-year-olds perform worse when an experimenter labels the dimension they need not attend to, but fail to explain why such labeling manipulations would benefit 4-year-olds. For example, under the active-latent account (Yerys & Munakata, 2006), labeling the first sorting dimension can lead to increased processing of the labeled dimension. This increased processing could cause young children to fixate on the labeled dimension, impairing their performance when they later have to switch. However, explanations from this framework do not account for the change in children's ability to use labels between the ages of 3 and 4. It is possible that developmental increases in working memory capacity and updating prevent the increased processing associated with labels to lead to fixation on the previous dimension once children need to switch. Such possibilities related to working memory should be tested in future studies, and explanations from the active-latent account could be extended to account for the findings.

Other accounts are compatible with the finding that 4-year-olds benefit from labels in cognitive flexibility tasks, but do not explain why labels would impair performance in 3-year-olds. For example, the levels of consciousness (LoC) model (Zelazo, 2004) suggest that children form a hierarchical system of rules that can integrate two contrasting rules underneath a higher order rule. For example, a 4-year-old would be able to understand that three images can be sorted in two different ways, and be able to successfully choose a second pair after being shown one by the experimenter. Under this framework, for children who are capable in principle of adopting a higher level of consciousness, labels create a more robust representation of the sorting dimension that can be decoupled from the objects being labeled and can therefore allow children to more easily integrate the sorting rule into their rule hierarchy (Jacques et al., 2007). However, this framework does not speak directly to the effect of labels for children who are unable to adopt this higher level of consciousness. Children may be impaired by labels because the more-robust representation cultivated by labels cannot be integrated into a rule hierarchy in a task effective way and instead leads to fixation on the first sorting rule. Future work should test whether individual differences in the ability to form hierarchical representations correlates with beneficial effects of labels on cognitive flexibility, to extend the LoC account to explanations of labeling manipulations in younger children.

Future directions could include an individual differences study looking at how working memory capacity and cognitive flexibility with labeling manipulations may be correlated within individuals. Past research has suggested that working memory capacity was predictive of flexible thinking in 4 and 5-year-olds, and that 3-year-olds who did better on working memory tasks score higher on cognitive flexibility tasks (Chevalier et al., 2012). Running the FIST coupled with a working memory task could support the interpretation of present results. If working memory plays a strong role in active representations and manipulating information, children who are able to use labels effectively should score higher on working memory tasks, such as the Nebraska Barnyard task (adapted from the Noisy Book task; Hughes et al., 1998), a task that requires children to remember and manipulate a series of animal names. Investigating the correlation between working memory performance and cognitive flexibility measures and looking at whether these skills develop synergistically could shed light on the underlying mechanism behind labeling manipulations on the FIST.

Another future direction for this work could be in the field of education and intervention. Studies have shown that preschool children can be trained on working memory and inhibition tasks (Thorell, Lindqvist, Bergman, Bohlin, & Klingberg, 2009), though transfer of such training to everyday life has been relatively inconsistent and should be further explored (Melby-Lervag & Hulme, 2012). Specifically, cognitive flexibility training has been shown to be successful in preschoolers and older children by integrating executive function into daily activities, such as play and aerobic exercise (Diamond & Lee, 2011). Thus, in light of this recent work suggesting cognitive flexibility can be improved, the present finding that labels impede cognitive flexibility in 3-year-olds will be especially important to consider when designing training program and intervention strategies for this age group.

Overall, this work has helped to identify the informative and important role of labels in the development of cognitive flexibility across preschool. While it appears that 3-year-olds are impaired by the labeling of a sorting rule right before needing to switch to a new sorting rule, other work suggests that 4-year-olds can benefit from the introduction of descriptive labels to a complex task, perhaps due to a relatively more mature working memory system that allows them to hold multiple active representations in mind. This work helps to clarify opposing findings from previous studies, and is relevant to broader questions about how language supports adaptive behavior. Future studies should aim to further specify the relationship between language and cognitive flexibility across preschool, to provide a broader understanding of the complex relationship between these two fundamental yet complex skills.

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