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Young children's analogical problem solving:

Gaining insights from video displays

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Abstract

This study examined how toddlers gain insights from source video displays and use the insights to solve analogous problems. Two- to 2.5-year-olds viewed a source video illustrating a problem-solving strategy and then attempted to solve analogous problems. Older but not younger toddlers extracted the problem-solving strategy depicted in the video and spontaneously transferred the strategy to solve isomorphic problems. Transfer by analogy from the video was evident only when the video illustrated the complete problem goal structure, including the character's intention and the action needed to achieve a goal. The same action isolated from the problem-solving context did not serve as an effective source analogue. These results illuminate the development of early representation and processes involved in analogical problem solving. Theoretical and educational implications are discussed.

Key Words: Analogical transfer, Problem solving, Learning, Video, Tool-use strategy.

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Introduction

When children encounter a problem to solve, they can tackle the problem using any number of approaches: trial-and-error; recall of a successful everyday-life experience in a different context; or generalization of an insight gained from a family story, a storybook, or a television program (e.g., Tomasello, 1999; Siegler, 1995, 2000). Although there is evidence of the usefulness of two-dimensional displays, such as those in storybooks, for toddlers' problem solving, the effectiveness of video displays as a source of successful analogical transfer, and the components needed to gain such insights, remain largely unexplored. The present research therefore examines whether toddlers can gain insights from video displays, and the conditions under which they use those insights to solve analogous problems.

Analogical transfer of problem-solving strategies involves the retrieval of acquired strategies or solutions and their application to isomorphic tasks (Goswami, 2006). The success of transfer of strategies from familiar to novel problems depends on the distance between the deep structure of the two problems and the degree to which the problems share superficial features; it also reflects how deeply a child represents source strategies and how effectively the child maps source and target problems. Generalization of strategies is a key dimension of change in children's thinking and a critical measure of learning (Siegler, 2006).

The basic paradigm for examining analogical transfer involves presenting source analogues that illustrate problems and solutions, and observing subsequent solutions to isomorphic problems. Even preschoolers have been shown to exhibit analogical transfer on the basis of structural similarity (e.g., Brown, 1989; Holyoak, Junn, and Billman, 1984). For example, Brown, Kane, &

Echols (1986) presented preschoolers with the "Genie" problem that required moving jewels over an obstacle by rolling the Genie's magic carpet into a tube through which the jewels could be transferred. The experimenter then presented a different cover story with toy props and asked the children to solve a problem in which a bunny needed to deliver its Easter eggs across a river. Three- and 4-year-olds were able to transfer the source solution to the structurally similar target problem by rolling the bunny's blanket (a piece of cardboard) into a tube through which the eggs could be transported.

Infants and toddlers also have been shown capable of analogical problem solving, provided that the source analogues are presented in the form of live demonstrations and the children actively participate in learning the analogues. One- and 2-year-olds can reenact a sequence of modeled actions (e.g., Bauer & Mandler, 1989) and generalize observed live demonstrations of actions to novel materials (Bauer & Dow, 1994; Hayne, MacDonald, & Barr, 1997) and novel contexts (Barnat, Klein, & Meltzoff, 1996). Very young children have also proved capable of constructing relatively abstract and flexible mental representations of source problems and transferring a modeled solution strategy across analogous problems (Chen, Sanchez, & Campbell, 1997). For example, 18- to 35-month-olds showed effective transfer of a tool-use strategy across a series of isomorphic problems after observing an experimenter demonstrating with an appropriate tool how to solve an analogous problem that differed in several superficial characteristics (Chen & Siegler, 2000). Previous studies have thus demonstrated one- to three-year-olds' ability to transfer strategies across isomorphic problems if the children observe live demonstrations and engage actively in exploring the source problems (Brown et al, 1986; Chen & Siegler, 2000).

Studies with older children have demonstrated that their problem solving can also be guided by other media and forms of source analogues. For example, 4- and 5-year-old children can extract the meaning of pictures they view and use the experience to solve a physical insight problem analogous to that which the source pictures depicted (Chen, 2003), and 5- to 8-year-olds can effectively use verbal stories as source analogues for problem solving (Chen, 1996; Tunteler & Resing, 2007). However, despite the robust demonstration of children's ability to transfer problem-solving strategies from source analogues in the form of live demonstrations, pictures, and stories, little is known about when children achieve the ability to use video displays or video animation as source analogues to guide their problem solving.

Although analogical transfer in children with this medium is largely unexplored, ample evidence from imitation studies points to infants' and toddlers' ability to imitate gestures and sequential actions demonstrated in a video format (e.g., Barr, 2010; Barr & Hayne, 1999; Meltzoff, 1985, 1988; Troseth, 2003). One reason to suspect that videos would not produce analogical transfer in such young children is that despite their impressive early abilities to imitate gestures and actions displayed on video, infants and toddlers learn significantly less effectively from videos than from live demonstrations (DeLoache & Burns, 1994; Hayne et al., 2003; Troseth, Saylor, & Archer, 2006), a phenomenon referred to as the video deficit effect. Children's performance in the imitation studies tended to occur under optimal experimental conditions with brief delays between viewing and reenacting the observed actions, verbal instructions aimed at facilitating imitation, repeated exposure to the video displays, and/or displays depicting familiar contexts. Whether such young children can show efficient learning from video displays under less optimal conditions was the main issue addressed in the present study.

The study examined the processes/components involved in young children's acquisition of insights from source video displays and use of the insights to solve analogous problems. The initial process hypothesized to influence learning was <u>encoding</u> the solution/strategy depicted in the source story, picture, or video. In an analogical transfer paradigm, transfer depends on learners representing intentions, actions stimulated by the intentions, and whether the strategy led to goal attainment. The second process involves noticing the analogous relation between the video demonstration and the subsequent target problem. In an analogical learning paradigm, the source video and the problem may share few superficial features; the perceptual dissimilarities create a potential obstacle to noticing the analogy between source and target problems (Chen & Daehler, 1992; Gentner et al., 1993). The third component involves mapping the goal structures and solution strategies between the source video and target problems. The analogical alignment process is guided by the shared relational structures of the analogous tasks; mapping these underlying structures can present a great challenge to successful transfer, especially in younger children (Brown & Campione, 1981; Gentner, 1989; Gentner & Toupin, 1986; Goswami, 1995; Halford, 1993).

Solving problems by video analogy poses a considerably more difficult challenge than imitating actions in the video; infants and toddlers might well prove incapable of analogical transfer at ages when they can imitate actions successfully. The analogical transfer paradigm used in the present research differs from the imitation of video-displayed actions in several key aspects. First, in imitation studies, the actions modeled on video are presented in more or less isolated fashion, but in the present study, the video-displayed source analogue illustrates a problem and a strategy for solving it, both of which are embedded in a problem-solving goal structure. The more complex information increases the difficulty of encoding the source problem depicted in the video. Second, in typical imitation tasks, the features of the objects in the video and those used for reenactment are identical, and children are often reminded of what was demonstrated in the source video by the experimenter's verbal request to re-enact the actions (Hanna & Meltzoff, 1993). In contrast, in the present task, the video and target problem-solving tasks involved different objects and contextual features, and no verbal cues were provided to remind toddlers to use the information from the source video to solve the target problem. The distance between the video displays and the target problem-solving tasks was thus considerably wider than on previously examined imitation tasks, increasing the challenge of noticing the analogous relations. Third, children can succeed on the imitation task by simply retrieving the actions that they encoded in the source video, whereas in the present analogical transfer paradigm, children need to adapt that strategy to the demands of the target problem. In other words, the correspondences between the key elements of the source video displays and the target problem need to be mapped so that those elements are maintained in the face of changes in incidental features of the problems and therefore in the specific actions needed to attain the goal. Thus, the present paradigm differs from previous imitation procedures in terms of the cognitive components required to succeed on the task.

The specific goals of the present study were 1) to examine developmental differences in toddlers' ability to solve physical problems by gaining insights from source videos, 2) to test how structural features of the problem and solution strategy illustrated in the video affect analogical transfer, and 3) to explore the roles of specific processing components involved in gaining analogical insights from videos.

Relative to previous studies that examined developmental differences in children's learning from video displays, the distance between the video demonstration and the target problem–solving phase was greater in the present study. In the present videos, the experimenter wore a panda costume, which she did not wear in the target problem-solving setting. Furthermore, no verbal hint suggesting the video's potential usefulness for solving the target problem was provided to the child. Moreover, several distractors (irrelevant objects) were present in the video. Thus, the children faced a greater challenge than in experiments in which superficial similarities, helpful instructions, and absence of distractors facilitated analogical transfer.

Toddlers were assigned to one of two conditions. In the Goal Directed condition, children watched a “panda” utilize a tool to obtain an out-of-reach apple on a table. In the Isolated Action condition, the “panda” demonstrated the same action but did not use it to retrieve another object. We tested the hypothesis that the structural features of the source video (i.e., whether the video display depicted the goal structure of the problem and its solution) would affect young children’s ability to represent and use the observed strategy to solve the target problems.

Method

Participants.

Seventy-two typically developing 2- to 3-year-olds participated in the study. Toddlers in each age group were randomly assigned to either the Goal-Directed Action condition (2-year-olds: n = 18, M = 25.6 months, SD = 1.95; 2.5-year-olds: n = 19, M = 32.9 months, SD = 1.91) or the Isolated Action condition (2-year-olds: n = 16, M = 25.5 months, SD = 1.83; 2.5-year-olds: n = 19, M = 32.8 months, SD = 2.01). Five additional participants were tested but not included in final data analyses due to equipment failure, experimenter error, or toddler fussiness. Approximately equal proportions of girls and boys were assigned to each condition at each age level.

Materials.

Source Video Clips. The character in each of the two source videos was an adult dressed in a panda costume. In the Goal-Directed Action condition, the video showed the panda seated at a table with an apple placed beyond the panda’s reach. Three tools -- a cane with a long shaft and a head at a right angle to it, a similar shaft with no head, and a spoon head without a shaft -- were placed on the table between the panda and the apple. The panda first showed its intent by stretching its arm toward the apple but failing to reach it. The panda then looked at the tools and chose the most effective one, the cane, to pull the apple close enough to reach. The panda demonstrated the goal-directed action with the cane twice.

In the Isolated Action condition, the video illustrated the same action in isolation from the problem-solving context. As in the other video, the apple and tools were placed right in front of the panda, and the panda picked up the cane and twice demonstrated the action of moving the cane slowly forward and back. However, the panda completed this action without touching the apple or otherwise indicating a desire for it. Both videos included light background music but no narration and lasted approximately 2 minutes.

Target Tool-Use Tasks. Three isomorphic target problems, which differed in surface features but shared underlying problem structures, were presented. These problems and the strategy needed to solve them were analogous to the problem and solution in the Goal-Directed Action video. Each included an attractive toy (a toy turtle, telephone, or Ernie doll) that lit up and played music and that was placed beyond the child's reach. On each task, 6 tools were placed between the toy and the child (Figure 1). Each set of tools included 1 target tool (a long tool with an effective head), 1 tool with an ineffective head (a long stick with a small round head), 2 shafts (long sticks without heads), and 2 heads (one short rake head and one short hoe head). Only the target tool had the long shaft and effective head needed to obtain the toy. In each of the other target tasks, different tools were presented atop their own table. The target tools for Tasks B and C were a hoe and a rake, respectively. Thus, the target tool on Tasks B and C included heads that had been ineffective on Task A. On each table, a transparent box was used to cover the tools before the trial began.

Procedure.

The experimenter greeted the child and parent(s) in a large room. After the child became comfortable in the setting, the experimenter said, “Let’s watch a movie, OK?” The child and experimenter then watched the video clip twice. The video was shown on a TV with screen dimensions of 16.5 X 12 in.

After the second viewing, the child was guided to the other part of the room, which contained the three tables housing the target problems. The experimenter said: “Now, let’s do something else; let’s play a game,” lifted the transparent box covering the first target display, and asked the child to obtain the toy. There were three 60-second trials per target problem. After each trial, regardless of whether the child solved the problem correctly, the tools were randomly rearranged in a different left-to-right order, and the toy was returned to its original location.

After the third trial, approximately 2 minutes elapsed before the experimenter guided the child to the next table for the next problem. No verbal statements were made before the child attempted to solve the second and third tasks. The same three target problems were presented to children in both conditions in the same order. If a child was unable to obtain the toy on the last trial of the third problem, the experimenter demonstrated how to get the toy with the target tool and encouraged the child to try to get it by him/herself.

Results

To determine whether children transferred the analogous information from the source display, two measures of target-problem solving were used: 1) whether the target tool was chosen first (i.e., first picking up the ladle, hoe, and rake on Tasks A, B and C, respectively), and 2) solving the target problem by successfully obtaining the toy with the target tool. We used these two measures to assess how effectively children were able to transfer the tool-use strategy reflected in the video analogue. For example, one child might pick up the target tool on the first touch and subsequently use it to solve the target problem successfully. Another child might initially pick up the tool with the effective head but fail to solve the target problem. A third child might not choose the target tool first but select it later in the trial and solve the problem with it. By measuring both first tool choice and successful problem solving, we were able to more completely assess children's learning and transfer of the tool-use strategy than if only one of the measures were used. Two observers who were not familiar with the experimental design independently scored 22 randomly selected participants (a total of 198 trials). Agreement between the two observers was 93% on both initial target tool choice and successful problem solving.

Preliminary analyses showed no gender differences. Initial analyses also revealed no main effects of problem set, suggesting that children did not improve their problem-solving over the three isomorphic problems. Given that no feedback was provided between trials and between problems (three trials for each problem) and no hypotheses were formulated concerning the possible practice effects of trials and problems, the data were thus collapsed across the three trials and three problems.

The results of toddlers' performance in solving the target problem are organized to answer questions concerning 1) age differences in use of the source video to solve target problems and 2) effects of the video analogues' structural features on analogical transfer.

Choosing the Target Tool First.

A 2 (condition) X 2 (age group) analysis of variance was performed on the number of the 9 trials on which children picked up the target tool first (Figure 2). This analysis yielded main effects of condition, $F(1, 68) = 4.41$, $p < .05$, $MSE = 11.21$, $\eta^2 = .06$, and age, $F(1, 68) = 18.15$, $p < .001$, $MSE = 46.07$, $\eta^2 = .21$. Given that the interaction between condition and age approached significance, $F(1, 68) = 3.82$, $p = .055$, $MSE = 9.69$, $\eta^2 = .05$, a post hoc *t* test was conducted for each age level. These tests revealed a difference between the two conditions for the older group, $t(36) = -2.35$, $p < .05$, $\eta^2 = .16$, but not for the younger group, $t(32) = -.17$, $p = .87$. These analyses suggest that only the older toddlers' likelihood of touching the target tool first was increased by watching the Goal-Directed Action video.

Solving the Target Problem Using the Target Tool.

A 2 (condition) X 2 (age group) analysis of variance was performed on the number of times each child obtained the toy using the target tool on the nine trials (Figure 3). The ANOVA yielded main effects of condition, $F(1, 68) = 5.21$, $p < .05$, $MSE = 37.80$, $\eta^2 = .07$ and age, $F(1, 68) = 20.46$, $p < .001$, $MSE = 148.52$, $\eta^2 = .23$, and a marginally significant interaction between condition and age, $F(1, 68) = 3.13$, $p = .08$, $MSE = 22.72$, $\eta^2 = .04$. A post hoc *t* test at each age level again revealed differences between the two conditions for the older group, $t(36) = -2.41$, $p < .05$, $\eta^2 = .14$, but not for the younger group, $t(32) = -.53$, $p = .59$. These analyses reveal that only older toddlers in the Goal-Directed Action condition learned from the source video analogue.

Discussion

The primary goal of the present research was to explore toddlers' analogical problem solving following illustration of a useful solution strategy in videos. The results indicated that 2.5-year-olds are capable of extracting a problem-solving strategy introduced on television screens and spontaneously transferring the source strategy to solve isomorphic target problems. Children younger than 2.5-year-olds did not show such analogical transfer from watching the same video. These results point to developmental differences in children's abilities to identify the main point of the video (that to obtain the toy, a tool with an appropriate shaft and head was needed) and also differences in execution of an appropriate strategy (use of that tool to obtain the toy).

Forms of Analogical Problem Solving.

Analogous messages necessary for problem solving can be presented in various forms, including verbal statements, real-life displays, pictures, and video scenes. Young children have demonstrated extensive and flexible skills in solving problems by analogy from diverse sources such as live models (Chen & Siegler, 2000), verbal stories (Tunteler & Resing, 2007) and pictures (Chen, 2006). Another form of analogue involves video scenes. This is a particularly important potential source of information, given the omnipresence of television shows, DVD's, Youtube clips, etc. Numerous studies have demonstrated young children's ability to imitate actions from video presentations (e.g., Meltzoff, 1988; Barr & Hayne, 1999) and to use televised scenes as source information for locating objects in a life-size room (Schmitt & Anderson, 2002; Troseth & DeLoache, 1998; Zelazo, Sommerville, & Nichols, 1999). The present study provides evidence that toddlers also are able to use video demonstrations as source analogues for problem solving, even in the absence of statements that point to the relevance of the video to a physical situation and in the face of differences in the appearances of the actors in the video and physical situation.

Effects of Representing the Goal Structure.

The present study shows that 2.5-year-old children in the Goal-Directed Action condition gained insights from the source video analogue that helped them solve the target problems. What is clear from the difference between the older toddlers' performance in this and the Isolated Action conditions is the importance of presenting the problem goal structure for successful transfer. Only when the character demonstrated the intended goal and the action necessary to achieve the goal was transfer evident. Merely demonstrating the appropriate motion with the effective tool in isolation from the broader goal structure had no effect on either age group.

The present and previous findings thus suggest that how children represent a source problem structure affects their subsequent transfer. In order to imitate a demonstrated action, young children need only encode and retrieve the action depicted in a video. However, to learn and transfer a strategy to novel problems, children need to represent this strategy in connection with its intended goal, a challenging task for young children. Understanding the intention of others' actions emerges in the first year of life (Gerson & Woodward, 2012), and infants can benefit from active training, in contrast to observational experience, to identify the goal of using a tool (Sommerville, Hildebrand, & Crane, 2008). With age, children become increasing capable of representing a source problem's goal structure, a vital step towards successful analogical transfer in problem solving. The differential problem-solving performance between the Goal-Directed and Isolated Action conditions among older toddlers thus sheds new light on the development of early representation and analogical problem solving.

Developmental Differences in Transfer.

Despite infants' impressive ability to imitate gestures and actions from video displays, the capacity to transfer visual information presented within the framework of a problem-solving goal structure is a skill that develops after infancy. Even when a complete goal structure was illustrated in the source video, 2-year-olds did not successfully use the problem-solving strategy to solve the target problem, though 2.5-year-olds did so. The explanation for this fragile understanding likely involves developmental differences in several key cognitive components. As these components develop, we begin to see advances in transfer of video analogues to real-world problems.

The initial process of transfer involves representing the goal structure of the source problem. This critical component presents a challenge to young children, presumably all the more so when source videos, which deny toddlers the active experience that might help them represent the goal structure, are used (Sommerville, Hildebrand, & Crane, 2008). It seems likely that toddlers in the Isolated Action condition failed to transfer the source solution action at least in part because they did not perceive the action as a potential way to attain the goal in a physical problem-solving context. The second component involves noticing the analogous relation between the video display and target problem. The source video and target problems were analogous, but the transfer tasks involved different objects, tools, and characters/people. It was thus challenging, especially for the younger toddlers, to notice the analogous relation between the video display and the target problem. The third component involves mapping the common underlying goal structure between the source and target problems. The goal structure illustrated in the source video enabled older toddlers to map more effectively the correspondences of the causal relations among the goal, action, and outcome to the target problem, and thus facilitated transfer of the action as a problem-solving strategy. In the Isolated Action condition, children's mapping was impeded, presumably because the action in the source video was not embedded in a problem-solving goal structure.

The present findings shed some light on age differences in the processing components involved in analogical transfer, but fully understanding the obstacles that children at different ages experience in transferring problem-solving strategies from video scenarios to physical situations will require a great deal of additional research. Using a componential analysis as part of future investigations will allow the exploration of the processes involved in video analogical problem solving, and it will also permit a more precise pinpointing of the sources of difficulties children encounter when they try to apply 2D video information to 3D real-world problems.

Conclusions.

Drawing analogies between video displays and real-world problems is a type of analogical transfer that even very young children can achieve. Whether young toddlers can transfer video demonstrations to solve real-world problems or whether the gap is too vast for their cognitive capacities needs to be further explored. The present findings demonstrate older toddlers' ability to represent the conceptual information in source videos and to use it to guide their subsequent problem solving. While this ability emerges at around 2.5 years, it is initially fragile and dependent upon an appropriate contextualization of the source analogy within a problem-solving goal structure. We know from diverse studies of children's analogical transfer that their transfer skills continue to expand and grow more robust with age. This will no doubt prove to be the case with children's video analogical problem solving as well. Thus, further exploration concerning how different forms of video analogues affect children's problem solving and how the different cognitive components impact young children's video analogical problem solving are likely to yield valuable theoretical and practical insights for understanding cognitive development.

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Figure Captions

Figure 1. An example of the Target Tool-Use tasks

Figure 2: Number of trials on which target tool was chosen first in the Isolated Action and Goal-Directed Action conditions.

Figure 3: Number of trials on which problem was solved in the Isolated Action and Goal-Directed Action conditions.

Figure 1. An example of the Target Tool-Use tasks

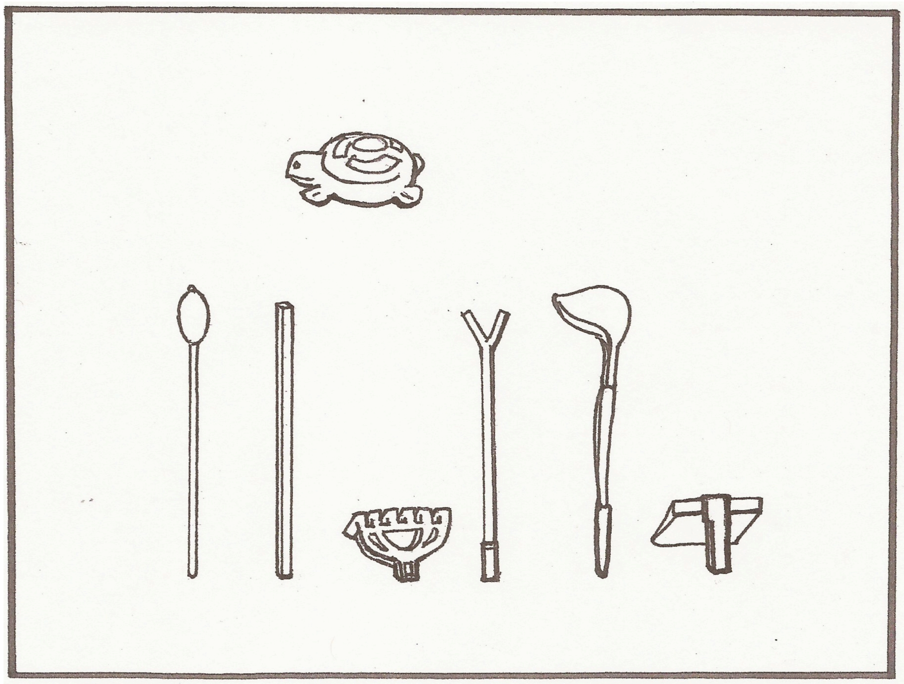

Figure 1: An example of the target tool-use tasks

Figure 2: Number of trials on which target tool was chosen first in the Isolated Action and Goal-Directed Action conditions

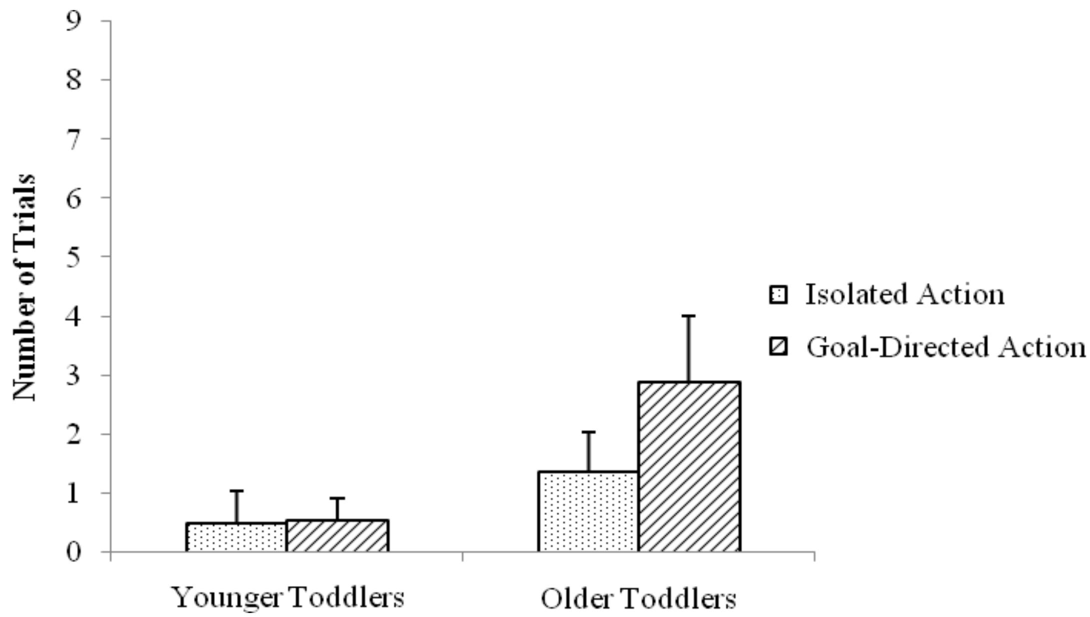

Figure 2: Number of trials on which target tool was chosen first in the Isolated Action and Goal-Directed Action conditions

Figure 3: Number of trials on which problem was solved in the Isolated Action and Goal-Directed Action conditions.

Figure 3: Number of trials on which problem was solved in the Isolated Action and Goal-Directed Action conditions