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PRESCHOOLERS IN PAIRS: WORKING TOGETHER IMPROVES MEMORY BUT NOT SKILL GENERALIZATION

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Morgan Hubble

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THESIS APPROVAL PAGE

This is to certify that the thesis prepared by Morgan Hubble entitled Preschoolers in Pairs: Working Together Increases Memory but not Skill Generalization has been approved by the thesis committee as satisfactorily completing the thesis requirements for the degree Master of the Arts.

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Kerri Goodwin, Committee Member — Date: 5/13/13

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Abstract

PRESCHOOLERS IN PAIRS: WORKING TOGETHER IMPROVES MEMORY BUT NOT SKILL GENERALIZATION

Morgan Hubble

This study examined preschool children's ability to remember details from learned tasks and solve novel problems using learning that occurred collaboratively with peers. Children were classified as poor or good problem solvers, paired with other children to build novel toys, and were later tested individually to see if they remembered their original training and generalized building skills to put together a novel toy. Influences on memory and generalizability, such as children's ability level, who they worked with, and language ability, were examined. Results suggest that preschool children remembered more information when working in pairs than when working alone, but they did not solve novel problems any better as a result of working in pairs. These results have important implications regarding the benefits of collaborative problem solving in preschool classrooms and other educational settings catering to very young children.

Keywords: Collaborative learning, problem solving, memory, generalization, pre-school

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Preschoolers in Pairs: Working Together Improves Memory but not Skill Generalization

Introduction

Problem solving is a skill that is necessary for survival and daily functioning. The cognitive processes we use to solve problems are complex and extensive, therefore, psychologists are keenly interested in how these processes develop. Problem solving plays a major role in planning (Zelazo, Carter, Reznick, & Frye, 1997), is grounded by certain types of executive functions (e.g., working memory; Zheng, Swanson, & Marcoulides, 2011), and associated with school readiness (George & Greenfield, 2005). In addition, research shows children benefit when they collaborate with adults on problem solving tasks that require shared task responsibility (Gauvain & Rogoff, 1989; Sun & Rao 2012; Hammond, Müller, Carpendale, Bibok, & Liebermann-Finestone, 2012), and if paired appropriately, they also benefit from collaborating with other children (Gauvain & Rogoff, 1989; Azmitia, 1988; Fawcett & Garton, 2005; Garton & Pratt, 2001). These benefits, however, are typically measured over short periods with school-aged children. This paper will explore the potential longer-term benefits of collaborative problem solving for preschool children.

Between ages 3 and 5, children go through several developmental changes in memory and executive functioning, such as the ability to think about and plan for the future (Naito & Suzuki, 2011). Other developmental changes include advancements in social interactions, which include more social play, a decrease in solitary play, and play that involves assisting others (Lyytinem, 1991). As a result of these developments, children show major improvement in creating strategies to solve problems between age 3 and 5, so that by the time they are 5, they can solve multi-step problems that require higher levels of working memory, inhibitory control, and prospective memory (Atance & Meltzoff, 2005; Atance & Jackson, 2009).

The current paper reviews the development of problem solving, ranging from simple tool-use in young infants to more complex levels of problem solving and planning exhibited by school-aged children. Problem solving is discussed in the context of several cognitive processes, including working memory and planning. Next, research on children's collaborative learning with adults, as well as peer-groups, is reviewed. Here, both the costs and benefits of collaborative learning are discussed and several components that may lead to optimal collaborative pairing are suggested. Finally, the current literature on collaborative efforts and long-term gains in learning is critiqued, and a new study to extend the current research is conducted.

Problem Solving Development

Problem solving is defined as the cognitive process that includes discovery, analysis, and solving of a particular problem or obstacle, and can be divided into three components that must be integrated in order attain a goal: (a) motor development (tactile perception and object manipulation), (b) perception (both visual and tactile), and (c) cognition (memory and planning; Keen, 2011). For infants and young children, these three components have also been referred to simply as object manipulation, visual perception, and memory, respectively.

With regard to object manipulation, infants are able to reach for and grasp objects by the time they are 4 months old (Jeannerod, 1996). Infants become increasingly adept at manipulating objects as they mature, with substantial changes in their motor control development occurring between 7 and 9 months of age (Rochat, 1992; Spencer, Vereijken, Diedrich, & Thelen, 2000). Despite these age-related advances, the ability to coordinate motor control with a plan of action, in order to solve a problem, has not yet developed. For example, McCarty, Clifton, and Collard (1999) examined the way in which 9-, 14-, and 19-month-olds grasped spoons presented in various ways. In this study, infants were offered a spoon, presented horizontally, so that the handle of the spoon faced either to the left or right. All infants reached for the spoon, but the age groups differed in how they executed the reach. At 9 months, infants did not plan their motor movement to coordinate with their goal (i.e., grasp the spoon comfortably). Regardless of the spoon's orientation, 9-month-olds reached for the spoon in the same manner with the same hand, resulting in the spoon being held in an awkward position, and making obtaining food nearly impossible. By 19 months of age, however, children were able to grasp the spoon with the correct hand, or manipulate the object so that a comfortable grip could be achieved. This study shows that the ability to coordinate cognition, action, and perception in order to solve a problem emerges sometime between 14 and 19 months of age.

In addition to motor development, visual perception is present at birth and improves rapidly in the first few months of life. Because young infants are lacking in both cognitive and motor skills, visual perception is their first way to explore the world. In preferential looking tasks, infants as young as 7 months can discern patterns (Kawabata & Gyoba, 2011), detect asynchronies between face and voice (Walker-Andrews, 1986), and even determine differences in numbers of objects (Starkey, Spelke, & Gelman, 1990). Infants typically show looking preference for novel objects and this discernment is thought to be the first step towards discriminatory problem solving and preliminary evidence of cognitive processes at work (Rose, Gottfried, Melloy-Carminar, & Bridger, 1982). However, while infants may be able to detect salient differences between two objects during a preferential looking task, they do not necessarily understand why the two objects differ (Wetherford & Cohen, 1973).

As visual perception develops and motor control is mastered, children begin to show significant advances in cognition as well. Shortly after the first year of life, children begin to combine the three components necessary for problem solving. Chen, Sanchez, and Campbell (1997) found that 13-month-olds were able to use their problem solving to transfer knowledge from a previous problem to solve a new one with items that were perceptually similar. In this study, infants were presented with a toy that was out of their reach. In order to obtain the toy, infants needed to move a clear barrier, pull a cloth that contained a string attached to the toy, and pull the string toward them. As an added component, there were two cloths in front of the infant, but only one connected to the string. Using trial and error, infants were able to determine which cloth brought them the string, and in turn, the toy. Infants were presented with the same problem two additional times using different cloths and toys. Results indicated that infants were able to solve analogous problems more efficiently during the second and third trial, even though testing materials changed, demonstrating that 13-month-olds were not only able to solve a novel problem using trial and error, but were also able to transfer their knowledge to a similar, yet novel, problem.

Thus, there is early evidence of problem solving in the three domains of visual perception, object manipulation, and memory. Motor control development arises early in development, but it is not until around 19 months that children begin to coordinate motor control with thought to achieve a goal (McCarty, Clifton, & Collard, 1999). Similarly, 6-month-olds may have fleeting representations for occluded objects, but they do not have the cognitive ability to mentally hold and process several steps or hidden objects (Rose, Gottfried, Melloy-Carminar, & Bridger, 1982). It is not until the second year of life that convergence of these skills becomes apparent, and more sophisticated problem solving skills emerge (Bauer, Schwade, Wewerka, and Delaney, 1999).

For children ranging in age from 2- to 5-years-old, Zelazo, Carter, Reznick, and Frye (1997) separate problem solving into a four-step process including (a) representation, (b) planning, (c) execution (i.e., intending, rule use), and (d) evaluation (i.e., error detection/correction). DeLoache (1987) examined representational ability of 30- and 36-month-old children. In this study, children were shown a three-dimensional model of a room and watched as an Experimenter hid a small replica of a toy in the model room. Children were asked to find the corresponding full-size toy in a room set up exactly as the model room. The 30-month-olds were only able to do so 15% of the time, but the 36-month-olds were able to understand that the model room represented the full-size room and locate the toy 77% of the time. These results suggest that young children are able to use representations to solve problems around the age of three.

With regard to planning, Bauer, Schwade, Wewerka, and Delaney (1999) investigated problem solving with 21- and 27-month-old children, and found that the older children were more likely to solve novel problems successfully. In addition, older children were able to use their problem solving skills for similar yet novel tasks, and also showed evidence of planning. Most importantly, children were able to use their knowledge of the end-state configuration to appropriately complete sub-goals leading to the overall end-goal. In one task, children were presented with the rattle while the experimenter labeled the toy ("Look, this is a rattle!"), and showed the children how the rattle worked. The toy was disassembled out of view, and children were presented with individual pieces and asked to build the rattle. In order to achieve the goal-state, steps had to be completed in a specific order. Therefore, proficiency in this task was assessed by examining the number of correct actions produced, and the number of correct ordered pairs produced. Children that were able to produce a high number of correctly ordered pairs and only the required amount of correct actions showed evidence of planning, compared to children who frequently repeated the correct actions without achieving a high number of ordered pairs, which exhibited more evidence of trial and error (Bauer et al., 1999).

In another task, children were given intermediate steps, but were not shown the final product. Interestingly, children were only able to assemble the toy when the final, goal-state step was shown to the children (Bauer et al., 1999). These results showed that there were age-related changes in problem solving skills, with 27-month-olds showing higher evidence for planning than the 21-month-olds, as evidenced by the number of correct ordered pairs and correct actions. Importantly, children did not differ on number of correct actions produced, only on the number of ordered-pairs produced and achievement of the goal-state. Despite the early onset of skills necessary for problem solving, planning capabilities with regard to novel problems, develop later, between ages 3 and 5 (Atance & Meltzoff, 2005; Atance, 2008).

Problem Solving and Planning

Planning is defined as a method worked out beforehand for the accomplishment of an objective (McCormack & Atance, 2011). One may effectively solve problems without planning the solution through a process of experimentation, however using planning in order to solve a problem increases success of attaining problem goals (Sheeran & Orbell, 1999). Central features of planning include thinking ahead, goal setting, and using systematic strategies to achieve goals. The process of thinking ahead or constructing a scheme beforehand is related to problem solving (Zelazo, Carter, Reznick, & Frye, 1997). Planning a future action, in concordance with problem solving, requires at least a two-step process, because the solution to the problem is not overtly evident (Bauer et al., 1999). For example, in the Tower of Hanoi task, which involves strategically moving discs of different sizes onto pegs in order to duplicate a model, planning must be used to achieve the solution that is not readily visible. There are a multitude of other tasks thought to tap the planning aspect of problem solving. These include delay of gratification tasks that measure both inhibitory control and prospective memory (Atance & Jackson, 2009), as well as prospective memory tasks that assess the ability to remember to do something in the future (Naito & Suzuki, 2011). In the classic delay of gratification task, children are instructed to delay their gratification by waiting to receive two marshmallows as a reward, instead of receiving one marshmallow immediately. This involves inhibitory control (i.e., suppressing the automatic response to eat one marshmallow immediately) and prospective memory (i.e., remembering that there is a greater reward in the future).

In addition to planning, there are several cognitive skills that develop during preschool that aid in advanced levels of problem solving. These include working memory and inhibitory control (Alp, 1994; Diamond, Prevor, Callender, & Druin, 1997). Working memory, or the ability to actively retain and manipulate information, is necessary for imagining future events (Atance & O'Neil, 2001). All components of Baddelely's (1986) model of working memory, including the phonological loop, visuo-spatial sketchpad, and central executive, consistently predict certain types of problem solving skills, such as accuracy for math word-problems in elementary school children (Zheng, Swanson, & Marcoulides, 2011). Specifically, the phonological loop is used to translate numbers to verbal code, and also used for rehearsal of numbers to be remembered. The visuo-spatial sketchpad is used to mentally represent the problem or components of the problem (e.g. carrying numbers). Finally, the central executive draws on both these components of working memory, and controls processing and attention (Zheng, Swanson, & Marcoulides, 2011).

Working memory is tied closely to inhibitory control, which involves suppressing irrelevant information, or inhibiting a dominant response, in order to achieve a goal (Wolfe & Bell, 2004). Inhibitory control is a necessary component of working memory, in that working memory involves the active manipulation of information, as well as the suppression of irrelevant information. An example of an inhibitory control task used with children is called 'day/night', and consists of a series of cards with pictures of either a sun or moon on them. Children are asked to say the opposite of what they see on the card. In order to achieve the goal, they are required to suppress a dominant response, which is to say what they see on the card. This task is also considered a working memory task, because children are required to hold two rules in their mind (call the moon ‘day’, and call the sun ‘night’) and actively apply the rules. Children begin to improve on this task by age three, and usually master it by age four (Wolfe & Bell, 2004).

Planning begins to emerge between ages 3 and 5. Welsh (1991) found that 3-year-olds showed little evidence of planning in the tower of Hanoi task, but 4- and 5-year-olds performed on par with children ages 8 and 9. Hudson and Fivush (1991) found similar results, but also found that 3-year-olds showed evidence of planning with support from adults. In this study, children were asked to plan a trip to the grocery store. Older 4- and 5-year-old children were better planners than the 3-year-old children overall, relying less on support from an adult to effectively plan. However, the 3- and younger 4-year-olds showed improvements in planning abilities when supported by adult. Working collaboratively with the support of an adult, and even working collaboratively with a peer, can lead to greater achievement in problem solving tasks.

Although 3-year-old children show more sophisticated levels of problem solving, they still require a large amount of assistance and show a lack of generalization skills. However, by age 4, there are significant advances in problem solving skills that are consistent with findings that show brain maturation of the prefrontal cortex during this age (Marshall, Bar-Haim, & Fox, 2002). In brain-imaging studies, the prefrontal cortex is the main area of the brain that is used when performing various executive function tasks (Wolfe & Bell, 2004). Based on these advances in brain maturation around age 4, it is apparent that children have the cognitive capacity to benefit from collaborative interactions. However, little research explores collaborative learning with young, preschool age children.

Collaborative Problem Solving

Throughout their lives, children learn effectively through instruction and interaction with teachers, parents, and family members (Pellegrini, Brody, & Sigel, 1985). In fact, collaboration is essential for optimal learning in young children. First introduced by Vygotsky (1978), collaboration with a more knowledgeable partner is also known as social scaffolding, or the process by which "more competent people provide a temporary framework that supports children's thinking at a higher level than children could manage on their own" (Siegler, DeLoache, & Eisenberg, 2003, p. 164). In social scaffolding information is taught based on the level of the learner, and through optimal support, adults are able to help children achieve at higher levels than they would on their own (Wood, Bruner, & Ross, 1976, cited in Siegler, DeLoache, & Eisenberg, 2003). Another type of collaboration, peer collaborative learning, is defined as two "children working together to complete a single, unified task that represents the shared meaning and conclusions of the group as a unit" (Fawcett & Garton, 2005, p. 158). Although collaborative problem solving has been researched for many years with adults and older children (Azmitia, 1988; Fawcett & Garton, 2005; Gauvain & Rogoff, 1989; Perlmutter et al., 1986; Schmitz & Winskel, 2008; Tudge & Winterhoff, 1993), few research studies have examined collaborations between preschool age children.

While evidence indicates that children can learn from peers as well as adults (Jaswal & Neely, 2006), it is unclear if one group facilitates learning better than the other. Rakoczy, Hamann, Warneken, and Tomasello (2010) found that when given the choice, 3- and 4-year-old children selectively learned the rules of a game from adults more effectively than from their peers. In this study, children were shown a game, and instructors on a screen (i.e. Two adults, or one adult and one child) demonstrated the game in conflicting ways. Children chose to mimic the actions of the adult significantly more than the child, suggesting that children view adults as more reliable than other children.

Jaswal and Neely (2006) also found that children consistently chose to learn from adults over their peers when given the choice. However, in this study, children looked to their peers for instruction if the adult proved unreliable. In this study, children watched adults either correctly or incorrectly label objects. If an adult was consistently unreliable at labeling objects, children relied on their peers for the correct demonstration. Additionally, there are studies that show that children will rely more on peers for certain kinds of information, such as questions about toys (Rakoczy, Hamann, Warneken, & Tomasello, 2010). Thus, although children rely on adults for information in general, there are instances in which children readily rely on their peers for instruction and information.

Given the right conditions, children can effectively learn from their peers. The peer must be seen as reliable, and considered knowledgeable about the subject (Tudge & Winterhoff, 1993; Schmitz & Winskel, 2008). Azmitia (1988) found that preschoolers were highly aware of their own, as well as their peers', competence level in a problem solving task. Additional factors associated with effective peer learning include communication (Fawcett & Garton, 2005), knowledge, and the qualitative value of the interaction itself, including the information that was shared in the collaborative context (Azmitia, 1988).

Azmitia (1988) discusses the underlying processes of collaborative problem solving in the context of three well-known learning theorists – Piaget, Bandura and

Vygotsky. Piaget viewed cognitive development in terms of conflict, and believed that cognitive growth was the result of seeking a mental equilibrium when conflict arose. Because conflict may arise in social situations, this particular study assessed the relationship between disagreements that arose during peer interaction and learning at post-test. Vygotsky viewed both cognitive and social development in terms of novices and experts. In this theory, a more experienced partner assists and instructs a less experienced partner in order for learning to take place. In order to assess this, this study used a pretest to determine expertise level in block building, and then coded behaviors of both experts and novices to determine the frequency of explanations, demonstrations, and monitoring of their partner. Finally, research shows that children of all ages learn by observing, as noted by Bandura (Esseily, Nadel, & Fagard, 2010; Horner 2001). The authors assessed this by coding the behaviors of both experts and novices to determine the amount of time spent observing and/or imitating their partner.

Results of the study indicated that children in peer groups were more accurate builders than children working on their own, and that low ability children benefited the most from working with high ability peers, reinforcing Vygotsky's and Bandura's theories (Azmitia, 1988). Azmitia's research was unique because it studied both the benefits of peer collaboration in terms of task performance, and factors that may play a role in facilitating this process. Interestingly, tasks engagement did not differ between pairs or individuals, which is contrary to the findings from Perlmutter, Behrend, Kuo, and Muller (1989). Azmitia's results suggest that preschool age children benefit from observational learning and guidance by an expert, but perhaps have not developed the cognitive capacities to handle conflict and engage in strategies on their own.

Fawcett and Garton (2005) extended the findings of Azmitia (1988) by facilitating peer collaborative problem solving through a block sorting task. In this study, children were individually pre-tested on sorting competency, and, based on their score, placed into high and low sorting-ability groups. Subsequently, children were then tested in same-sex pairs or alone. Children were paired into groups of ability that included two children with high ability, two children with low ability, or a mixed ability dyad. Finally, all pairs were assigned to either talk, or no-talk conditions. In the no-talk condition children were told explicitly not to talk, while in the talk condition, children were encouraged to talk. In both conditions, children were instructed to work together. Finally, children received individual post-tests of sorting ability.

Results from this study showed that low-ability children improved considerably from pretest to posttest when paired with high-ability children. Additionally, high-ability children paired with low-ability children also showed improvement, but these gains were not as robust. This may have indicated that consolidating existing skills, rather than developing new ones, was also important to high-ability children. Two low-ability children paired together improved only slightly at posttest in the talk and no-talk conditions. Conversely, two high-ability children actually tended to regress in both the talk and no-talk conditions, which the authors attributed to boredom (Fawcett & Garton, 2005).

The most important result of this study is that low-ability children performed significantly better on the sorting task when working with high-ability children. However, this result was mediated by communication, because while low-ability children paired with high-ability children improved slightly in the no-talk condition, high-ability children paired with low-ability children actually regressed in block sorting ability when they were not allowed to talk. Overall, low-ability children paired with high-ability children seemed to benefit most when communication was allowed (Fawcett & Garton, 2005).

The collaborative problem solving studies previously mentioned shed light on young children's development of generalized problem solving skills, but few research studies have explored collaborative problem solving with preschoolers, and none that have measured both memory for solved problems and generalization of problem solving skills after an extended delay. Current studies only use a short-term delay (typically a few days), or no delay at all. It remains unclear whether the beneficial effects of collaborative problem solving remain stable over longer periods of time. In addition, the majority of studies researching peer collaboration typically include school-age children, and rarely examine children younger than 5. However, there are a multitude of cognitive processes critical to problem solving that develop between the ages of 4 and 5 and therefore, it is important to examine collaborative problem solving at this age. In addition, children typically transition from preschool to kindergarten at the age of 5 and are often required to work in pairs or groups throughout grade school. Thus, pairing very young children may be useful to cognitive development in terms of enhancements to learning, and also a good strategy for socializing children, since children are required to work with others throughout their lives.

Obtaining a better understanding of how and when collaborative efforts with a peer may facilitate learning is important to the field of developmental psychology, and relevant to teaching practices within pre- and elementary schools.

The Present Study

The present study focused on age-related changes in collaborative problem solving in preschool aged children and measured both memory and generalization of problem solving skills for novel tasks. Additionally, this study identified factors that may mediate collaborative problem solving, such as level of expertise during the interaction and language ability. This study included a first visit where children were grouped according to their ability, referred to as the “grouping visit”, a training session where children worked alone or with a peer, referred to as the “training visit”, and a test session where children were individually tested, referred to as “test”. Both memory for a problem solving task and generalized problem solving ability were examined.

The dependent variables in this study are (a) children’s memory for the problem solving task introduced during the training visit, and (b) children’s ability to generalize problem solving skills for a novel problem given to them to solve during test, referred to as 'memory' and 'generalizability', respectively. The independent variables in this study are age (4 or 4.5) and group, which is based on individual children, as well as individual children within a paired group. These five groups are: 1) low-ability child working independently, 2) high-ability child working independently, 3) low-ability child working with a high-ability child, 4) high-ability child working with a low-ability child, and 5) a low-ability child working with another low ability child.

In regard to generalizability, performance was measured as change over time from the grouping visit to the test visit. In regard to between subject effects, I hypothesized that children age 4.5 would perform better than children age 4, on both measures of generalizability. I hypothesized that children age 4.5 would perform faster than children age 4 for generalizability task time. I also hypothesized that there would be significant differences between groups, and expect to see differences between individual children and children in mixed-ability pairs. I also hypothesized that there would be an interaction between age and group.

With regard to the within-subjects variable, I hypothesized that we would find significant differences in performance between the grouping visit to test. I also expected to find interactions between age and visit, group and visit, and a three way interaction between age, group, and visit.

In regard to memory, I hypothesized that children age 4.5 would remember more information than children age 4, for both measures of memory. I hypothesized that children age 4.5 would perform faster than children age 4 for the memory test. I also hypothesized that there would be significant differences between groups, and expect to see differences between individual children and children in a mixed-ability pair. Finally, I hypothesized that there would be a significant interaction between age and group.

Lastly, I hypothesized that during Visit 2, children working in pairs would have faster task times than individual children overall, that children with faster task times would be more likely to complete the task, and that children age 4.5 would have faster task times that children age 4. I also expected to find a significant interaction between age and group.

Method

Participants

One hundred children ages 4 and 4.5 years were needed to complete the study, and 130 children were recruited from local pre-schools to participate. One hundred and seven children participated. Six children fell between the criteria for low and high ability and were excluded from subsequent analysis. Fourteen children did not return for the final visit, and one child was shy and did not give assent to participate for the final visit, so the task was ended immediately. Fifty-one of the children had a mean age of 46.84 months and fifty-six had a mean age of 53.02 months. Within the younger group there were 24 girls and 27 boys, and in the older group there were 30 girls and 26 boys. The total sample included 54 girls and 53 boys. Same gender pairs were used because research indicated that same gender dyads results in greater shared goals and consequently better performance (Strough, Berg, & Meegan, 2001; Strough & Cheng, 2000; Strough & Diriwachter, 2000).

Materials

All children were administered the Parent or Teacher Administered Language (PORTAL) tests (Stromswold, 2006), which measure articulation, lexical, and syntactic abilities in children. This measure included seven short assessments measuring word articulation, lexical access and vocabulary, working memory, letter identification, vocabulary, syntax (sentence comprehension), and pattern recognition.

All of the children participated in three separate experimental sessions, and received a different novel problem solving task (i.e., making a toy) during each session. A pilot study conducted with each toy ensured that children were not able to produce solutions to any of the problems prior to seeing the end goal-state. Each of the three tasks contained five steps required to build the toy properly. The tasks involved steps that could be attempted individually, but the toy could not be constructed unless all five steps were accomplished. The three problem solving tasks were as follows:

1. Rattle (a small ball with a bell inside, a plastic Tupperware with a hole cut into the center, a circular piece with Velcro, and a cylindrical handle with Velcro). The solution to the problem involves turning the Tupperware containing into an upright position, putting the ball into the open slot, placing the circular piece over the mouth of the hole, placing the Velcro part of the cylindrical handle over the Velcro part of the circular piece, and shaking the rattle. Children are told that they must use all pieces to obtain the correct solution.
2. Spinning top (Plastic circular base, two plastic balls, spiral plastic piece, plastic cover, and handle crank). The solution involves placing spiral piece on the base, placing the balls around the spiral piece, covering the base with the plastic cover, placing the crank on top, and spinning the top around.
3. Gong (Wooden base with triangular supports, bar attached to one support with a hinge, latch to serve as a resting place for the bar on the other hinge, S hook, metal plate, wooden mallet). The solution involves placing the latch on a wooden support in order to bridge the gap between 2 supports at one end of the base, placing the wooden bar on the latch to create a cross piece, hanging an S hook on the cross piece, hanging a metal plate on the S hook, and using the wooden mallet to hit the plate and make a gong sound.

Procedure

Visit 1: Grouping. Children were tested individually in their pre-schools. Children sat across from the experimenter at a child-size table. After obtaining child assent, either the "rattle" or "spinning top" task was presented to the child. Results of a pilot study indicated that although task order did not have an effect on performance, children scored equally on the "rattle" and "spinning top" tasks, while scores on the "gong" task tended to be slightly lower. Therefore, the "rattle" or "spinning top" were used during the first two "training" sessions. The more difficult task was used for the generalization test to ensure there were no ceiling effects. The testing procedure included the following three phases:

Baseline. The first phase served as a baseline measure to assess children's prior experience with the task objects. Children were presented with the disassembled parts of a particular task and encouraged to explore the objects. After ninety seconds, or until the child expressed disinterest in the objects, the objects were removed from the child's view and assembled completely.

Goal-state presentation. The goal-state presentation immediately followed the baseline phase. The experimenter presented the assembled goal-state object to the child and made a verbal statement of the goal. Accompanying this was a verbal label and physical action. For example, in the case of the rattle, the experimenter presented the assembled rattle and said "See, you can use this stuff to make a rattle". Then, the experimenter shook the rattle and said, "shake it". The experimenter presented the goal-state object two times in succession. After the second presentation of the goal-state, the object was removed and disassembled out of the child's view.

Response period. The response period immediately followed the goal-state presentation. Children were again presented with the disassembled task objects, and were directed to build the goal object. The experimenter said, "Now, use all of these pieces and build the rattle (Or spinning top, or gong)". Children were given 5 minutes to complete the task. If the child completed the task prior to the end of five minutes, the session was ended by the experimenter.

Language measure. At the end of the first visit, children were administered the PORTAL. For the first task, children's word articulation was measured by asking children to repeat 12 simple words (e.g. that). Two lexical access and vocabulary tasks were administered. For the first one, children were given a rapid naming task in which they were asked to name as many animals as they could in 30 seconds. The second task of this nature required children to rapidly name words in categories (e.g. name something cold). Next a working memory task was administered in which children were asked to remember seven non-sense syllables in the order they were presented. Letter identification required the children to identify 10 random capital letters, and two lowercase letters, and vocabulary required the children to identify eight random pictures (e.g. helicopter). In the syntax test, children were asked to choose the picture that matched a sentence that was read aloud (e.g. The dog licked the bear). Finally, pattern recognition required the child to identify the next shape in a series of shapes. There were 10 trials that increased in level of difficulty. All scores were converted to proportions, with the exception of naming animals, in which number of animals named was recorded.

Visit 2: Training. After scoring the response period from the Grouping visit, children were placed into either same-gender pairs or remained as individuals. The Training visit occurred one week after the Grouping visit. Children with a proportion score of .40 or lower were considered low-ability and children scoring .60 or higher were considered high-ability. Very few children fell between .4 and .6, and they were eliminated from analysis. There were two types of pairings: 1) a low-ability child paired with a high-ability child, and 2) two low-ability children. For Visit 2, the procedure for individuals was identical to Visit 1. The procedure for pairs was also identical to Visit 1, with the exception that pairs were instructed to work together. The experimenter said, "Now I want the two of you to work together and build the rattle. Work together and help each other, and remember, no fighting."

Visit 3: Test. Pilot testing revealed that 3 weeks was the optimal delay to avoid both ceiling and floor effects for retention and therefore, the test occurred three weeks after the training session. During test, children were given a memory assessment from the toy seen during the training visit, and were tested for generalized problem solving ability with a third novel problem solving task. The order of these two tasks was counter-balanced. For the memory assessment, children were asked to put together the toy from the training visit without seeing the goal-state presentation. Memory was assessed by comparing the difference in problem solving scores from grouping and test visits. For the generalized problem solving task, the procedure was identical to the grouping visit.

Coding. Three measures were used to characterize children's performance: a total score, a proportion score, and task time. A trained coder coded the video sessions for number of target actions produced. For the total score, each of the five possible target actions was counted once. If the child also completed the task, an additional point was given for task completion. Thus, scores ranged between 0 and 6. This is consistent with other literature using problem solving tasks that require several steps to build an object (Bauer, Schwade, Wewerka, & Delaney, 1999). The total score results will be the main focus of this paper; however, because the total score only accounted for the correct actions produced by the child, a proportion score was generated to take into account both correct and incorrect actions. This is consistent with research that measures collaborative learning with older children (Fawcett & Garton, 2005).

For the proportion score each target action counted once so that, although there are only five possible target actions, repetitions of these actions were counted. Next, actions that were irrelevant to building the goal-state object were counted. A proportion score between 0 and 1 was calculated for the number of target actions divided by the total number of actions.

Lastly, we measured task time and time-on-task. Time for this measure began when the child was presented with the toy during the response period, and ended when the child completed building the desired toy, or indicated that they were finished with the task. Five minutes was the maximum time allowed to build the toy, but no child reached this time limit. A child was considered on task if they were looking at the toy, manipulating the toy, or engaging in the process of building the toy when working with a peer.

Results

Preliminary analysis

A 2 (Gender) x 2 (First Toy: Rattle, Spinning Top) x 2 (Visit 3 task order: generalizability first, memory first) analysis of variance (ANOVA), and was performed on each of the dependent measures: generalizability and memory. With regard to generalizability task performance, there were no main effects for gender, $F(1, 99) = 0.341$, $p = .560$, $\eta_p^2 = .003$, first toy, $F(1, 99) = 0.767$, $p = .383$, $\eta_p^2 = .008$, or task order, $F(1, 99) = 0.115$, $p = .735$, $\eta_p^2 = .001$. With regard to memory task performance, there were no main effects for gender, $F(1, 99) = 0.543$, $p = .463$, $\eta_p^2 = .005$, or task order, *F*(1,

99) = 1.624, $p = .206$, $\eta_p^2 = .016$. However, there was a main effect of first toy on memory, $F(1, 99) = 36.133$, $p < .001$, $\eta_p^2 = .267$, revealing that the rattle was significantly easier to remember than the spinning top. Because the presentation of toys was counterbalanced across all conditions, any effects were equally distributed.

Covariates

Correlations were run for each sub-test of the PORTAL and our dependent measures of memory and generalizability. The pattern recognition sub-test was positively correlated with generalizability, $r(104) = .235$, $p = .015$, indicating that children who scored higher on pattern recognition were better at generalizability of problem solving skills. The category naming variable was positively correlated with memory, $r(105) = .266$, $p = .006$, indicating that children who scored higher on category naming remembered more information for the problem solving task. For the main analysis, these factors were included as covariates. Generalizability task time and memory task time were not correlated with any of the PORTAL sub-tests, $p > .05$.

Correlations

Correlations were run for each visit and their respective task times. Grouping visit performance was negatively correlated with grouping task time, $r(103) = -.234$, $p = .016$, training visit performance was negatively correlated with training task time, $r(105) = -.449$, $p < .001$, generalizability task performance was negatively correlated with generalizability task time, $r(105) = -.485$, $p < .001$, and memory task performance was negatively correlated with memory task time, $r(105) = -.430$, $p < .001$. For all visits, the child's ability to achieve target actions was negatively correlated with the time they spent on the task, indicating that as task performance increased, time spent on task decreased.

Training Visit

Task time. A 2 (Age: 4, 4.5) x 5 (Group: High-ability individual, low-ability individual, high-ability child in a low-high pair, low-ability child in a low-high pair, and low-ability child in a low-low pair) factorial ANOVA was conducted on the training visit task time. The analysis revealed a main effect of age, $F(1, 97) = 11.285$, $p = .001$, $\eta_p^2 = .104$, indicating that older children were faster at building the toy than younger children during the training visit. There was no main effect of group, $F(4, 97) = .752$, $p = .559$, $\eta_p^2 = .030$, and no interaction between age and group, $F(4, 97) = 1.374$, $p = .249$, $\eta_p^2 = .054$.

A 2 (Age: 4, 4.5) x 2 (Group: Pair, Individual) factorial ANOVA was conducted on the training visit task time. The analysis revealed a main effect of age, $F(1, 103) = 8.658$, $p = .004$, $\eta_p^2 = .078$, indicating that older children were faster at building the toy than younger children. There was an interaction between age and group, $F(1, 103) = 5.662$, $p = .019$, $\eta_p^2 = .052$, indicating that pairs at age 4 spent more time on the task than pairs at age 4.5. Figure 1 is a plot of the interaction between age and group. There was no main effect of group, $F(1, 103) = 2.187$, $p = .142$, $\eta_p^2 = .021$.

A 2 (Group: Pair, Individual) x 2 (Task completion: Completed, not completed) factorial ANOVA was conducted on training visit task time. The analysis revealed a main effect of group, $F(1, 103) = 3.967$, $p = .049$, $\eta_p^2 = .037$, indicating that pairs spent more time on the task than individuals. There was a main effect of task completion, $F(1, 103) = 27.992$, $p < .001$, $\eta_p^2 = .214$, indicating that task times were lower for children who completed the task. There was also an interaction between group and task completion, $F(1, 103) = 6.313$, $p = .014$, $\eta_p^2 = .058$, indicating that for those unable to complete the task, pairs spent more time with the task than individual children did. Figure 2 is a plot of the interaction between group and task completion.

Memory

Total score. A 2 (Age: 4, 4.5) x 5 (Group: High-ability individual, low-ability individual, high-ability child in a low-high pair, low-ability child in a low-high pair, and low-ability child in a low-low pair) factorial analysis of covariance (ANCOVA) was conducted on the memory total scores. There was a main effect of group, $F(4, 96) = 2.405$, $p = .055$, $\eta_p^2 = .091$. Bonferroni post hoc tests at the $p < .05$ level did not reveal any group differences, however, there was a trend towards significance for the difference between low-ability individual children ($M = 2.9$, $SE = .395$) and high-ability children in a low-high pair ($M = 4.5$, $SE = .405$), $p = .072$. Figure 3 is a plot of the group differences.

There was no main effect of age, $F(1, 96) = 2.804$, $p = .097$, $\eta_p^2 = .028$, and no age by group interaction $F(4, 96) = 1.297$, $p = .277$, $\eta_p^2 = .051$.

Proportion score. As with total score, results from a 2 (Age: 4, 4.5) x 5 (Group: High-ability individual, low-ability individual, high-ability child in a low-high pair, low-ability child in a low-high pair, and low-ability child in a low-low pair) factorial ANCOVA revealed a main effect of group on memory proportion, $F(4, 96) = 3.072$, $p = .020$, $\eta_p^2 = .113$. Post hoc tests revealed differences between low-ability individual children ($M = .505$, $SE = .061$) and high-ability children in a low-high pair ($M = .755$, $SE = .063$), $p = .058$, and low-ability children in a low-high pair ($M = .752$, $SE = .060$), $p = .045$, indicating that low-ability children benefited from working with high ability children. All other group differences were not significant, $p > .05$. Figure 4 is a plot of the group differences.

There was no main effect of age, $F(1, 96) = .452$, $p = .503$, $\eta_p^2 = .005$, and no interaction between age and group, $F(4, 96) = 1.018$, $p = .402$, $\eta_p^2 = .041$.

Task time. A 2 (Age: 4, 4.5) x 5 (Group: High-ability individual, low-ability individual, high-ability child in a low-high pair, low-ability child in a low-high pair, and low-ability child in a low-low pair) factorial ANOVA was conducted on memory task time. The analysis revealed no main effect of group, $F(4, 97) = .895$, $p = .470$, $\eta_p^2 = .036$, and no main effect of age, $F(1, 97) = 1.146$, $p = .287$, $\eta_p^2 = .012$. However, there was a significant interaction between age and group, $F(4, 97) = 2.397$, $p = .055$, $\eta_p^2 = .090$, and post hoc tests indicated that, for two low-ability children paired together, older children spent less time on the memory task than younger children. All other group differences were not significant, $p > .05$. Figure 5 is a plot of the interaction between age and group.

Generalizability

Total score. A 2 (Age: 4, 4.5) x 5 (Group: High-ability individual, low-ability individual, high-ability child in a low-high pair, low-ability child in a low-high pair, and low-ability child in a low-low pair) x 2 (Visit: Grouping Visit, Test) mixed model ANCOVA was performed on generalizability total scores. The total scores for generalizability violated the assumptions of Levene's test of equality of error variances, $F(9, 96) = 2.304$, $p = .022$, so the data were transformed. Because generalizability was a within subjects variable, the log was taken from the total scores for the grouping visit and test. After the data were transformed, Levene's test of equality of error variances was not significant, $F(9, 88) = 1.118$, $p = .359$.

The analysis revealed a main effect of group, $F(4, 87) = 8.799$, $p < .001$, $\eta_p^2 = .288$. Post hoc tests revealed significant differences between all high-ability children

(High-ability individual, *M* = .641, *SE* = .037; high-ability child in a low-high pair, *M* = .615, *SE* = .038) and all low-ability children, (Low-ability individual, *M* = .437, *SE* = .038; low-ability child in a low-high pair, *M* = .383, *SE* = .040; low-ability child in a low-low pair, *M* = .438, *SE* = .042), regardless of performing individually or in pairs. That is, all high ability children performed better than low ability children, regardless of whether or not they were in pairs.

There was an interaction between visit and group, $F(4, 87) = 3.232$, $p = .016$, $\eta_p^2 = .129$. Post hoc tests revealed that during the grouping visit there were significant differences between all high-ability children (High-ability individual, *M* = .704, *SE* = .041; high-ability child in a low-high pair, *M* = .650, *SE* = .042) and all low-ability children, (Low-ability individual, *M* = .354, *SE* = .042; low-ability child in a low-high pair, *M* = .310, *SE* = .045; low-ability child in a low-low pair, *M* = .405, *SE* = .047), regardless of performing individually or in pairs. At test, there were no significant differences between groups, $p > .05$. Thus, group differences were observed during the grouping visit but not at test, and differences were a result of ability and not pair type. Figure 6 is a plot of the interaction between visit and group.

There was no main effect of age, $F(1, 87) = 2.591$, $p = .111$, $\eta_p^2 = .029$, no interaction between age and group, $F(4, 87) = .383$, $p = .820$, $\eta_p^2 = .017$, no main effect of visit, $F(1, 87) = 1.661$, $p = .201$, $\eta_p^2 = .019$, no interaction between age and visit, $F(1, 87) = .145$, $p = .704$, $\eta_p^2 = .002$ and no 3-way interaction between age, group, and visit, $F(4, 87) = .235$, $p = .918$, $\eta_p^2 = .011$.

Proportion score. A 2 (Age: 4, 4.5) x 5 (Group: High-ability individual, low-ability individual, high-ability child in a low-high pair, low-ability child in a low-high pair, and low-ability child in a low-low pair) x 2 (Visit: Grouping Visit, Test) mixed model ANCOVA was performed on generalizability proportion. The proportion scores for the grouping visit violated the assumptions of Levene's test of equality of error variances, $F(9, 95) = 2.145$, $p = .033$, so the data were transformed. Because generalizability was a within subjects variable, the log was taken from the total scores for the grouping visit and test, in order to maintain consistency. After the data were transformed, Levene's test of equality of error variances was not significant, $F(9, 90) = 1.843$, $p = .071$.

The analysis revealed a main effect of group, $F(4, 89) = 14.917$, $p < .001$, $\eta_p^2 = .401$. Post hoc tests revealed that there were significant differences between all high-ability children (High-ability individual, *M* = -.159, *SE* = .030; high-ability child in a low-high pair, *M* = -.156, *SE* = .030) and all low-ability children, (low-ability individual, *M* = -.359, *SE* = .030; low-ability child in a low-high pair, *M* = -.386, *SE* = .031; low-ability child in a low-low pair, *M* = -.382, *SE* = .033), regardless of performing individually or in pairs. That is, all high ability children performed better than low ability children, regardless of whether or not they were in pairs.

There was a significant interaction between visit and group, $F(4, 89) = 8.845$, $p < .001$, $\eta_p^2 = .284$. Post hoc tests revealed that during the grouping visit there were significant differences between all high-ability children (High-ability individual, *M* = -.122, *SE* = .027; high-ability child in a low-high pair, *M* = -.102, *SE* = .207) and all low-ability children (Low-ability individual, *M* = -.483, *SE* = .027; low-ability child in a low-high pair, *M* = -.482, *SE* = .028; low-ability child in a low-low pair, *M* = -.486, *SE* = .030), regardless of performing individually or in pairs. At test, there were no significant differences between groups, $p > .05$. As with the total score, group differences were observed during the grouping visit but not at test, and differences were a result of ability and not pair type.

There was no main effect of age, $F(1, 89) = .695$, $p = .407$, $\eta_p^2 = .008$, no interaction between age and group, $F(4, 89) = .066$, $p = .992$, $\eta_p^2 = .003$, no main effect of visit, $F(1, 89) = .053$, $p = .819$, $\eta_p^2 = .001$, no interaction between age and visit, $F(1, 89) = .378$, $p = .540$, $\eta_p^2 = .004$, and no 3-way interaction between age, group, and visit, $F(4, 89) = .215$, $p = .929$, $\eta_p^2 = .010$.

Task time. A 2 (Age: 4, 4.5) x 5 (Group: High-ability individual, low-ability individual, high-ability child in a low-high pair, low-ability child in a low-high pair, and low-ability child in a low-low pair) x 2 (Visit: Grouping Visit, Test Visit) mixed model ANOVA was performed on generalizability task time. The assumptions of Levene's test of equality of error variances were violated for the grouping visit, $F(9, 95) = 4.127$, $p < .001$, and the test visit, $F(9, 95) = 3.072$, $p = .003$, so the data were dichotomized at the median.

The results revealed a main effect of age, $F(1, 95) = 4.404$, $p = .038$, $\eta_p^2 = .044$, indicating that older children spent more time on the task than younger children. There was a trend towards significance for group, $F(4, 95) = 2.152$, $p = .080$, $\eta_p^2 = .083$, and no interaction between age and group, $F(4, 95) = .585$, $p = .674$, $\eta_p^2 = .024$. There was no main effect of visit, $F(1, 95) = .001$, $p = .977$, $\eta_p^2 = .000$, no interaction between age and visit, $F(1, 95) = .330$, $p = .567$, $\eta_p^2 = .003$, no interaction between group and visit, $F(4, 95) = .217$, $p = .929$, $\eta_p^2 = .009$, and no 3-way interaction between age, group, and visit, $F(4, 95) = .116$, $p = .977$, $\eta_p^2 = .005$.

Discussion

This purpose of this study was to test young children's memory for assembling a complex toy, and their ability to generalize what they learned to help them assemble a new toy. Children participated in three visits, each containing a novel problem solving task. The first visit served as an initial measure of their problem solving ability, and to allow us to group them based on ability level. The second visit involved children working in pairs or alone on a novel problem solving task. During the final visit, children were tested individually on their on their memory for the task from the second visit and on generalization of problem solving skills with a novel problem solving task. Data were examined in terms of total score, proportion of correct to incorrect answers, and time it took children to complete tasks.

With regard to generalizability, results from the total score and proportion score showed that low performing children did not benefit from working with high performing children. The direction of performance was somewhat surprising -- children who were originally classified as having low ability on problem solving showed a positive change in generalizability scores from the first to the final visit, whether they worked alone or in pairs, while children who were originally classified as having high ability on problem solving showed a negative change in generalizability scores from the first to the final visit. Although group differences were observed, further investigation indicated that differences were observed during the grouping visit only, and were a result of ability level not pairing type. It was hypothesized that only low-ability children working with high-ability children would significantly improve their generalization skills from the grouping visit to test, however this was not the case.

It is possible that performance for all children merely regressed to the mean over time. However, it is also possible that for low ability children, simply doing a problem solving task helped them understand what was expected of them, so that they spent more quality time focusing and working on the next problem they encountered. This pattern of results might have also occurred because the final toy was more difficult than the original toys, leading to the suspicion that a better score for low ability children might indicate more understanding of the requirements of the task.

The direction of change observed in high-ability children, a slight decrease in performance, was consistent with other collaborative literature (Azmitia, 1988; Fawcett & Garton, 2005). Azmitia (1988) suggests that once children individually reach a certain level of proficiency in performance, collaboration becomes less influential on a child's gains in learning, because children at a high level of performance are more likely to be able to learn effectively on their own.

In addition, pattern recognition was a significant contributing factor to generalization of problem solving skills, which has been correlated with working memory, spatial reasoning abilities, and algebraic proficiency in older children (Logie & Pearson, 1997; Lee, Ng, Bull, Pe, & Ho, 2011). This comes as no surprise, considering the spatial nature of our tasks.

A similar pattern of results was observed for reaction time from the grouping visit to test, in that children who were classified as low ability spent more time on the task, and children that were classified as high ability spent less time on the tasks. Although results were not significant, it is interesting to note that as children's performance was improving, their task time was decreasing. This is consistent with our correlational analysis of reaction time and task performance for all visits, such that task time decreased as performance increased. Similar to the pattern seen in generalizability performance, the direction of change in all low-ability children showed decreases in task time from grouping to test, and all high-ability children showed slight increases in task time from the grouping visit to test.

These results, coupled with the results concerning generalizability performance, indicate that children ages 4 and 4.5 may not benefit from collaborative interactions in terms of generalization of problem solving skills. However, it is important to note that although children did not improve in terms of problem solving, they did not significantly drop in performance either. There are several explanations as to why preschool children do not improve their generalized problem solving skills as a result of working collaboratively with a peer.

In terms of cognitive development, research indicates that children go through several developmental advances in problem solving ability, via changes in executive functions, between ages 3 and 5 (e.g. increases in planning; Naito & Suzuki, 2011). As a result of these developments, children show major improvement in creating strategies to solve problems during the preschool years, so that by the time children are 5, they can solve multi-step problems that require various executive functions (e.g. higher levels of working memory, inhibitory control, and prospective memory; Atance & Meltzoff, 2005; Atance & Jackson, 2009). However, there are a wide range of individual differences in these cognitive skills, and it stands to reason that, although some 4-year-old children may be proficient problem solvers, others may be just beginning to master their skills.

Individual differences in social skills may also explain why we did not observe improvements in generalization of problem solving skills as a result of collaboration. Development of social skills during preschool include advancements in social interactions, such as more social play (Lyytinem, 1991). Research also suggests that social development and executive functions are intricately bound, and Miller and Markovitch (2012) found that children's theory of mind understanding was closely tied in with their executive function skills (Miller & Markovitch, 2012). This is of particular interest, because problem solving is grounded by certain executive functions, and these executive functions are also related to social skills which are important in collaborative interactions.

Theory of mind studies indicate that mastery of this concept does not occur until late in the fourth year of life (Flavell, 2004; Kaysılı & Acarlar, 2011; Shelton, Clements-Stephens, Lam, Pak, & Murray, 2012). If children are not yet able to understand the mental states of their partners, they may not benefit from collaborative interactions. As our task was dependent on both cognitive and social skills, young children may be doubly immune to the beneficial effects of collaboration that are seen in older children.

Fawcett and Garton (2005) suggest that the most effective partnerships in school-aged children occur when children are sensitive to their partner's needs, and use a high level of explanations for their actions. However, these are skills that 4-year-old children are still developing (Flavell, 2004). Future research should explore the level of social competency in preschool children, as it relates to their propensity to achieve gains in learning as a result of collaborative interactions.

Although collaborating did not result in improvements to generalized problem solving skills in preschool children, there were significant improvements in memory when children worked in pairs of differing ability. Children who were originally classified as low ability remembered significantly more information when working with children classified as high ability, than when they worked alone. In addition to low-ability children remembering more, high-ability children paired with low ability children also remembered more information. Thus, pairing and ability level play a crucial role in benefits to collaborative learning.

For a low-ability child to remember information at the level of a high-ability child after one collaborative interaction is a very important discovery, and speaks to the profound nature of children working together. This is particularly important because no other study has demonstrated improvements in memory as a result of collaboration in preschool children. Other research indicates the effect of pair type on generalizability is crucial (Fawcett & Garton, 2005; Garton & Pratt, 2001), and it is apparent that this finding also extends to memory for information learned in collaboration. We suggest that if one collaborative interaction improves memory significantly after weeks of time, it is a strategy worth using in the preschool classroom.

One reason that we observed improvements in memory and not generalizability may be that these cognitive processes require a different set of cognitive skills. It may be that generalizing information is more difficult than simply remembering information. That is, memory is distinct from generalizability, in that memory requires retrieval of information from long-term memory, while generalization requires memory for a set of rules or concepts that are to be applied to a new problem. Rittle-Johnson, Siegler, and

Alibali (2001) made this distinction in math problems, discussing the differences between procedural and conceptual knowledge. According to these authors, procedural knowledge consists of remembering a set of steps required to complete a specific problem, whereas conceptual knowledge involves remembering general steps or rules for a certain type of problem, and applying these to a new problem. In school-aged children, procedural knowledge always precedes conceptual knowledge in terms of math problems. Thus, it follows that advances in memory are seen before advances in generalizability, in regard to our novel problem solving tasks.

In regard to age, there were no significant differences between children ages 4 and 4.5 for either memory or generalizability. We believe a six month time frame may not have been a large enough time difference to see any changes in cognition at this age. Additionally, there is a large range of individual differences in rates of development and problem solving skills in general at this age, and thus comparing these two ages may not have been effective. However, there were significant differences in age for task time, such that, as children matured they become faster at problem solving. It is clear that the older and younger children were both able to benefit from collaborative learning interactions in terms of memory, and we believe this practice should be implemented into pre-schools as young as age 4.

The literature suggests two possible ways in which children in pairs show greater achievement in subsequent tests. Thinking of children in an interaction setting, we know that only children in pairs that differ in ability level later produce children that surpass the level of performance of individual children. During this interaction, the collaborative level exists on a continuum of how participative each child is. For example, it is possible that the high-ability child facilitates the learning of the low-ability child through social scaffolding and equal levels of participation on both children's part. In this regard, scaffolding, coupled with the physical manipulation of the action, could enhance memory for problem solving skill. Or, it may be that high-ability children take over the interaction, and low-ability children simply watch. Either way, this results in improvements to memory for problem solving skills at age 4.

If children participate in the interaction equally or close to equally, this is an example of social scaffolding, in which the high-ability partner is aware of their partner's ability, and interacts with them accordingly. This is consistent with literature that suggests that children are aware of their own, as well as their partner's competence levels by the age of 5. This again falls into the timeline of the major changes in development from ages 3 to 5. This may not be the traditional idea of social scaffolding that would achieve the level of performance to that of an adult, but the interaction is effective nonetheless. Simply taking the time to take turns (versus dominating the interaction) could be taken as a sign of scaffolding and appropriate social cognition. Along the same idea, scaffolding, by definition, involves cooperative interaction, which allows for children to equally manipulate parts of the toy. Early research concerning learning concluded that children learn better by doing versus observing (Droit, 1995), and some recent research indicates that this is still the case in certain domains (Goldin-Meadow, Levine, Zinchenko, Yip, Hemani, & Factor, 2012). According to this theory, collaborative interactions would need to have equal participation from both partners for benefits to occur. However, more current research indicates that this may not be the case (Steffens, 2007).

Research findings on scaffolding and imitation work well in explaining the benefits of an interaction if the children within the pair participate equally. However, it is possible that in some pairs high-ability children will be the dominant participant in the interaction, while the low-ability children simply watch. While some research suggests that children learn better by doing (i.e. enactment of the task), Steffens (2007) suggests that observation and enactment produce equal levels of learning. To support the idea that learning by doing is equal to learning by seeing, Foley and Ratner (1998) explored source monitoring errors of children when working collaboratively with an adult on a collage building task. Their results show that watching during a collaborative task has equal benefits for memory as does participating in the task itself.

In older children and adults, the pattern of source errors in collaborative tasks typically shows that if a participant cannot remember a collage piece being placed, they claim that their partner placed the piece rather than themselves. This would suggest that physically completing an action is more salient in memory. However, Foley and Ratner (1998) found the opposite effect. According to the source monitoring framework, cognitive operations are highly salient in memory (Johnson, Hashtroudi, & Lindsay, 1993). The results of Foley and Ratner (1998) support the idea that internal or imagined memories are easier to remember because of the cognitive operations associated with them, and this is consistent with the adult literature.

This study extends the evidence that collaborative efforts increase explicit memory, and gives explanation as to why. Thus, benefits to learning occur in collaborative interactions regardless of the children's participation level. As an interesting follow-up to our current study, we plan to code the videos from the training visit to determine the level participation from each partner. This will shed light on the method by which preschool children are gaining the most from collaborative interactions: watching, doing, or a combination of both.

In addition to improvements in memory, there are several reasons that collaboration is an important and positive way to facilitate learning during preschool. First, children in pairs did not work slower than individual children, indicating that, practically, having children working in pairs does not take up more time in preschool classrooms. In addition, there were no detriments to children's ability to generalize their skills to a new problem, and more information was remembered as a result of the collaborative interaction.

In addition to enhancements in remembering, another important reason to promote collaborative learning is that children enjoy working in pairs more than working alone. Perlmutter et al. (1986), using both self-report and observed behavior, found that peer-group collaboration not only improved retention of problem solving skills, but it also increased task engagement and positive affect. For 5-year-old children working in pairs, researchers found higher levels of positive affect towards the math and reading tasks than children who worked alone. As another interesting follow-up to the current study, we plan to code our videos for affect level during the training visit, to determine if there are differences between pairs and individuals.

Additionally, Perlmutter et al. (1986) found that 5-year-old children working in pairs stayed on task longer than those working alone, and children working in pairs had a higher proportion of correct answers during the test sessions. This is consistent with our findings, which show that children in pairs were more persistent at building than individual children, as indicated by their task time for toys they were unable to build. That is, pairs were less likely to give up building if the task proved difficult.

Working together is a way not only to improve memory, and as they age, generalization of skills, but also teaches important social skills (Fawcett & Garton, 2005). Fawcett and Garton (2005) found that children in pairs in which at least one child was able to provide explanations and were more sensitive to other students needs in a collaborative task performed better at post-test for a block sorting task. If children could be taught these skills early this could improve both social interactions and increase learning. Practically speaking, children are expected to work with peers throughout their years in school and on into adulthood. Thus, preschool age children are not too young learn important life skills, such as working collaboratively. If children can come into kindergarten prepared to cooperate with their peers, this is an essential skill to promote.

Limitations include the ages used in this research study. Unfortunately, 4 and 4.5 are not far enough apart to be sensitive to changes in the development of problem solving skills. Collaboration resulted in greater memory at 4 and 4.5, so future studies regarding memory should include a younger age group, such as 3.5, to determine if these improvements are seen in younger children. In regard to generalizability, an older age group, such as 5 or 5.5, should be collected to pinpoint the age that collaboration improves generalization of problem solving skills. Future research should expand on the ages used in our study, in order to determine if improvements to generalization occurs by age 5, as the literature suggests, and to determine if memory enhancements occur younger than age 4. Other limitations include only using same-gender pairs for our collaboration, because it is unclear if these effects would extend to mixed-gender pairs.

Future research should explore the qualitative differences in collaborative interactions for same-gender and mixed-gender pairs, and explore whether our results extend to mixed-gender pairs. Lastly, although we see enhancements in memory as a result of the collaborative interaction, it is unclear how these enhancements are achieved, and the literature suggests that there are two possible mechanisms by which collaborative learning may occur: 1) watching the collaborative interaction, or 2) participating in the collaborative interaction. Future research is needed to explore exactly how collaboration is facilitated.

Children in preschool are able to benefit from collaboration on problem solving tasks in terms of memory, and research indicates that by age 5, children will also improve generalized skills as a result of working in pairs. Thus, allowing preschool children to work in collaboration on problem solving tasks is developmentally appropriate. Overall, preschool children working in pairs show greater memory for a novel problem solving task than children working alone. Despite greater memory, there were no differences observed between pairs and individual children for generalized problem solving skills. While language and pair type play a significant role in both memory and generalizability, the use of collaborative problem solving in preschool is an effective tool to improve memory for certain skills and increase social cooperation.

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Figures

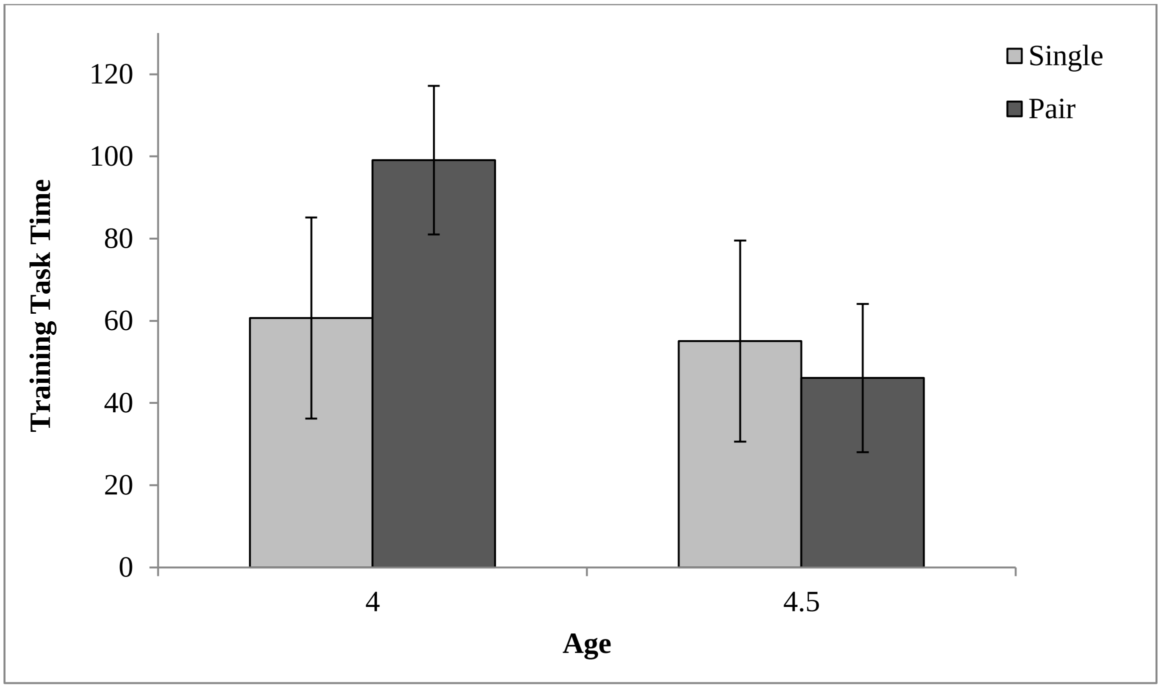

Figure 1. Age by group for training visit task time. Pairs at age 4 took significantly longer than pairs at 4.5, indicating that older pairs work faster than younger pairs. No differences were observed for individual children.

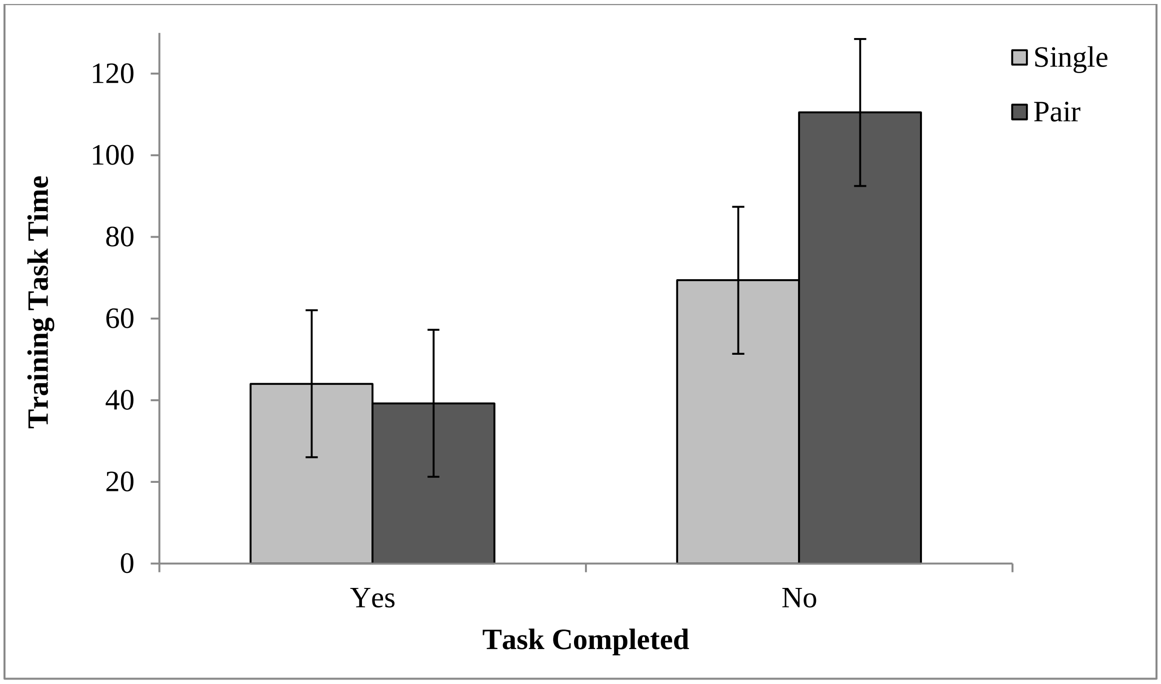

Figure 2. Task completion by group for training visit task time. For those that were unable to complete the task during the training visit, pairs spent significantly more time on the task than individual children, indicating that pairs were more persistent with the task than individuals.

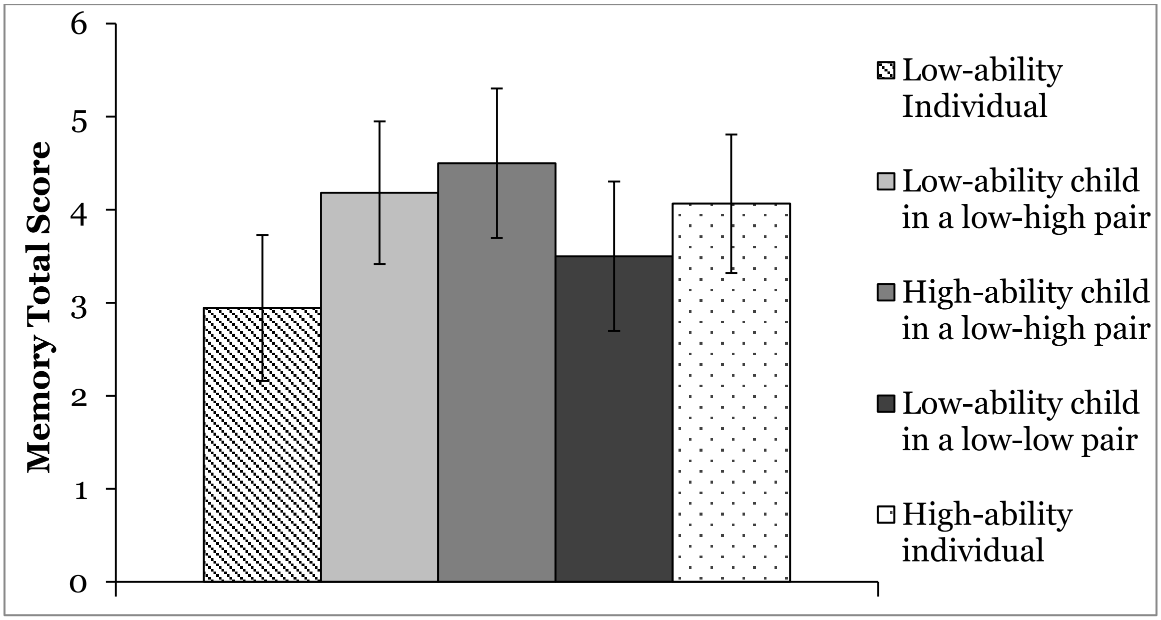

Figure 3. Mean scores for memory total score by group. No group differences were observed. However, a trend towards significance was observed between low-ability individual children and high-ability children in a low-high pair.

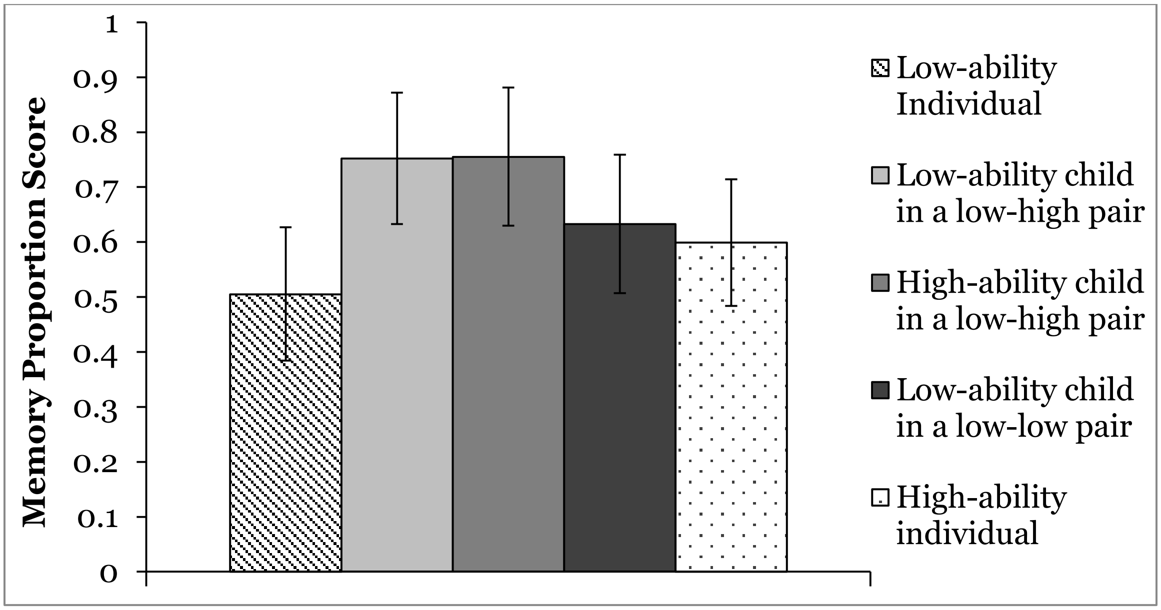

Figure 4. Mean scores for memory proportion by group. Significant differences were observed between low-ability individual children and low-ability children in a low-high pair. Differences were also observed between low-ability individual children and high-ability children in a low-high pair. This indicates that children in mixed-ability pairs remembered significantly more information than low-ability individual children.

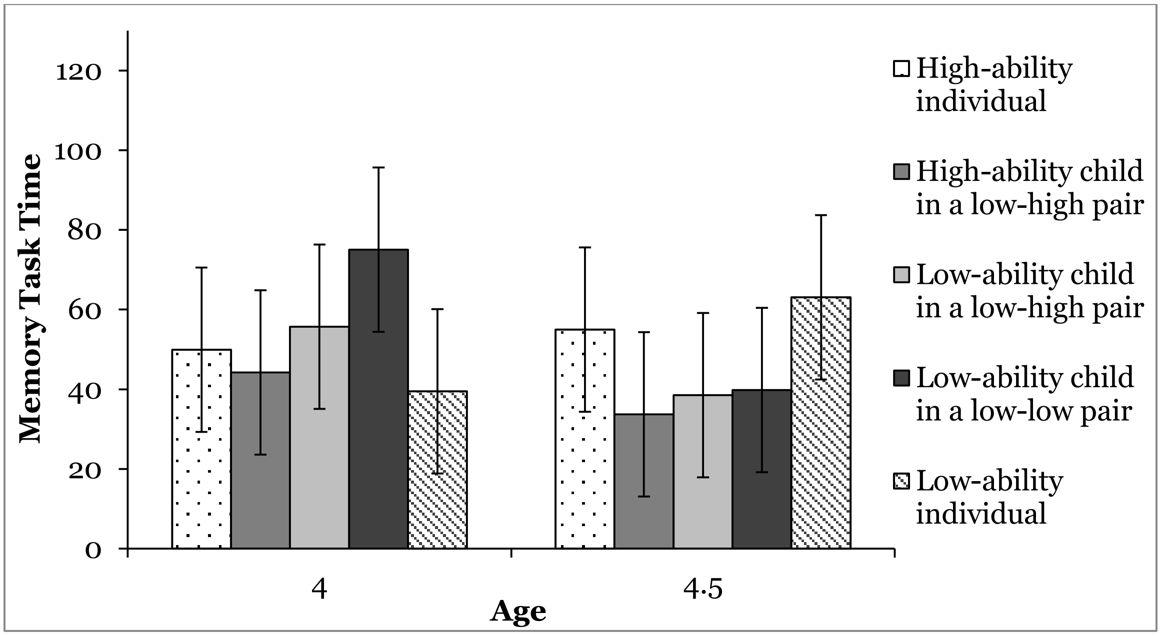

Figure 5. Age by group for memory task time. For two low-ability children paired together, significant differences were observed between age groups. This indicates that, for two low-ability children paired together, older children in this group spent less time on the memory task than younger children.

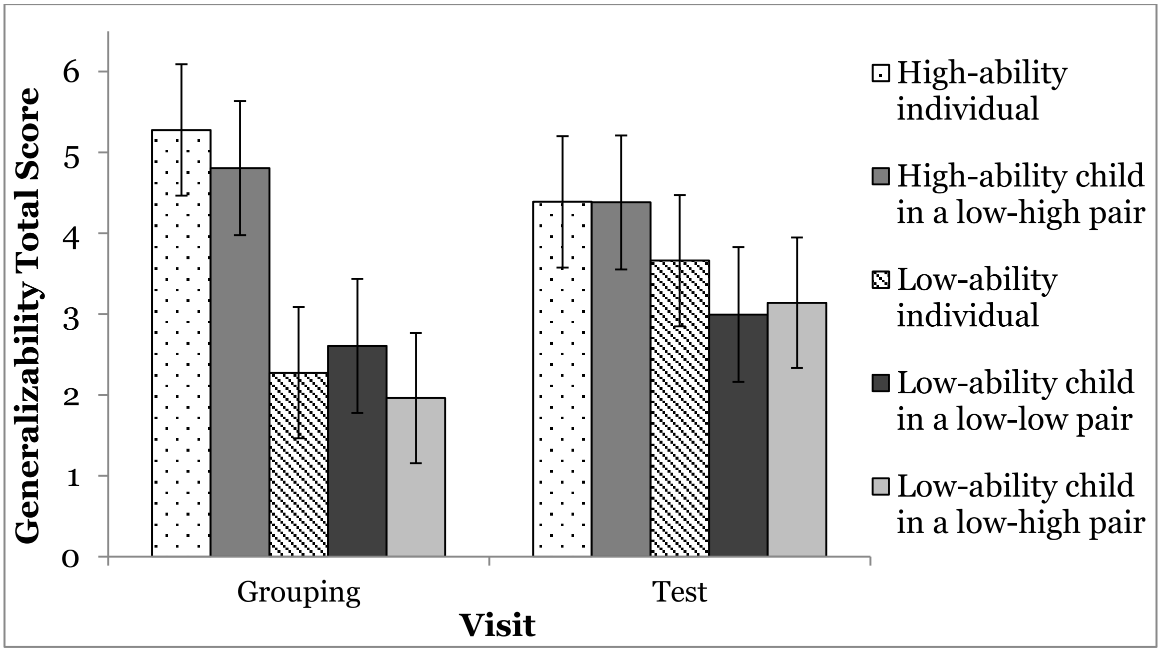

Figure 6. Visit by group for generalizability total score. For the grouping visit, significant differences were observed between all low-ability children and all high-ability children. No group differences were observed at test. This indicates that working in pairs did not significantly improve generalization of problem solving skills.

Curriculum Vita

Morgan L. Hubble
15 Debonair Court
Apartment T2
Parkville, MD 21234

Experimental Psychology
Master of Arts, 2013

Education

5/2013 M.A., Towson University, Towson, MD
Concentration: Experimental Psychology

12/2007 B.S., Virginia Polytechnic Institute & State University, Blacksburg, VA
Major: Psychology

Peer-reviewed Manuscripts

Cuevas, K., **Hubble, M.,** & Bell, M.A. (2010). *Early Childhood Predictors of Post-Kindergarten Executive Function: Behavioral, Parent-Report, and Psychophysiology.* Early Education and Development, 23, 59-73.

Presentations

Hubble, M., Kazlauskaite, V., Taylor, S., Sheffield, E.S. (2013). *Preschoolers in Pairs: Working Together Increases Memory for Problem Solving.* Poster session to be presented at the meeting of the Association for Psychological Science, Washinton, D.C.

Hubble, M., Watson, A.J., & Bell, M.A. (2012). *Correlates of Recall, Recognition, and Language at Ages 2 and 3.* Poster session presented at the International Conference on Infant Studies, Minneapolis, MN.

Hubble, M., Smith, R., Sheffield, E.S. (2012). *Heard but Not Remembered: Distorted Audio Decreases Children's Memory for Stories.* Poster session presented at the meeting of the Association for Psychological Science, Chicago, Illinois.

Hubble, M., Cuevas, K.C., & Bell, M. A. (2011). *Pre-School Predictors of School-Aged Executive Function.* Poster session presented at the Biennial meeting of the Society for Research in Child Development, Montreal, Canada.

Hubble, M., Morasch, K.C., & Bell, M.A. (2010). *Associations between Maternal Intrusiveness and Toddler Behavior.* Poster session presented at the International Conference on Infant Studies, Baltimore, MD.

<u>Positions Held</u>

8/2011 – 5/2013 Graduate Assistant for Assessment
Towson University
Campus Life Office
8000 York Road
Towson, MD 21252
Supervised by Dr. Teri Hall, Associate Vice President of Student Affairs
Campus Life Office, Towson University

3/2009 – 7/2011 Laboratory Manager
Virginia Tech
Psychology Department (0436)
Blacksburg, VA 24061
Supervised by Dr. Martha Ann Bell
Cognition, Affect, & Psychophysiology Laboratory (C.A.P. Lab)
Department of Psychology, Virginia Tech

1/2006 – 5/2007 Undergraduate Research Assistant.
Virginia Tech
Psychology Department (0436)
Blacksburg, VA 24061
Supervised by Dr. Martha Ann Bell
Cognition, Affect, & Psychophysiology Laboratory (C.A.P. Lab)
Department of Psychology, Virginia Tech

1/2006 – 5/2006 Undergraduate Research Assistant.
Virginia Tech
Psychology Department (0436)
Blacksburg, VA 24061
Supervised by Dr. Dagmar Hannesdottir, Anxiety Disorder studies
Child Study Center, Virginia Tech