PROBLEM SOLVING OF YOUNG CHILDREN

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ABSTRACT OF THE THESIS

Problem Solving of Young Children

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The current study examined and compared the problem solving of 18 to 22 and 27 to 36 months old children. These age groups are not commonly studied in this aspect because very young children cannot reflect on their own thinking or tell us about their problem solving strategies. In the study 24 children (11 younger and 13 older) were presented with tasks that required the use of tools to retrieve a desired object.

The results of the study showed similarities as well as differences between the two age groups’ problem solving. Children in both age groups devised and used a variety of successful and unsuccessful strategies during problem solving. The children’s strategy choices in general suggested that they had an understanding of the goals of the problems and the strategies needed to achieve these goals. There was a significant difference in the condition of success and the number of unsuccessful strategies the two age groups used. Significantly more children in the older age group succeeded independently and without using any unsuccessful strategies, showing that they used means-end analysis in their problem solving. Some of the older children and most of the younger children used one or two unsuccessful strategies before they succeeded (demonstrating the use of a hill-climbing strategy), which indicates that this problem solving strategy is prevalent in both age groups. Significantly more children in the younger age group used three unsuccessful strategies before they succeeded, indicating a trial and error strategy. Scaffolding (e.g. verbal or modeling help) was offered to those children who were not successful independently. The results show that verbal help was always sufficient help for the older children, but it was less sufficient for the younger children who needed modeling to succeed.

The practical implications of this study are important for parents and teachers of toddlers and preschoolers. The findings indicate that very young children are active problem solvers and use many different strategies during problem solving. The findings also indicate that by age three verbal hints can be an effective way to help children in problem solving situations, but for children younger than two years old modeling is more effective.
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CHAPTER 1

INTRODUCTION

One of the major foci of cognitive development research is to study the development of thinking. “Thinking, by definition, is a mental process that is private and not directly accessible to outside observers. How to get access to the inaccessible is the ultimate challenge for cognitive development research…” (Lee, 2000, p. 135).

Thinking is frequently studied by investigating how children solve problems. Detailed observations of children’s problem solving and the strategies they use at different ages can give us insight into how thinking changes with age. The majority of research on the development of problem solving has focused mainly on children old enough to explain their reasoning behind their solutions. Less is known about younger children’s problem solving. The current study investigates the problem solving of children between the ages of 18 and 36 months old. Very young children are not able to reflect on their own thinking and do not have the verbal skills to inform us about their problem solving strategies. This creates a challenging situation for experimental design. The design of the current study was based on tasks that required the use of tools to retrieve a desired object. The problems involved actions simple enough for young children to perform, interesting enough to keep them engaged and complex enough in underlying principles to challenge them to use different observable problem solving strategies. According to Chen and Siegler (2000), studying problem solving of young children through tool use is of interest because:

The ability to use tools to solve problems is a classic measure of intelligence in both people and nonhuman primates (Goodall, 1986; Kohler, 1925; Visalberghi & Limongelli, 1994); because such tool use requires understanding causal relations, a key part of early cognitive development (Keil, 1989; Leslie, 1982; Oakes & Cohen, 1995); and because efforts to solve the task generate a great deal of visible behavior from which strategy use can be inferred. (p. 17)

BACKGROUND

For this study data were analyzed from a segment of work completed in the Developmental Psychology Laboratory at San Diego State University (2001-2003) under the
supervision of Dr. Larry Fenson. The experiment involved 41 children who were recruited through advertisements in local publications and local day care centers. All children were tested and videotaped at the Developmental Psychology Laboratory with a parent present throughout the study.

**DESCRIPTION OF THE OVERALL EXPERIMENT.**

The overall study examined the problem solving behavior of 18 to 36 month old children when presented with tasks that required the use of a tool to retrieve a desired object. The goal of the study was to explore the problem solving and strategy use of young children.

The first phase of the experiment involved three colorful yarn balls and a wooden box with a hole in the top. The experimenter would drop the first yarn ball into the box and encourage the children to do the same with the other two yarn balls. The purpose of this phase was to familiarize the children with working with the yarn balls, and to establish the objective of the trials as putting yarn balls into the box.

Next, the children were presented with short and long clear tubes (2.5 and 8 inches), and a long opaque tube (8 inches) all mounted on a wooden platform, with a yarn ball lodged in each one. The children were encouraged to get the yarn balls out and put them in the wooden box. The experimenter provided a tray of tools (wooden rods) along with the tubes. The tray contained effective tools (correct length and diameter) and ineffective tools (correct length, incorrect diameter or shape). The children could get the yarn ball out of the short (2.5 inches) tubes by reaching with their fingers. However the only way to succeed in retrieving the yarn balls from the long (8 inches) tubes was to choose and use an effective tool (a wooden rod). These introductory tasks served the purpose of familiarizing the children with the tools and the basic nature of the tasks.

Next, more complex problems were presented to the children, children’s responses to these problems are the main interest of this study and will be closely examined and analyzed. These trials involved an extra long (14-inch) transparent tube with a yarn ball lodged in it (see Figure 2, p. 13), and an inverted T-shaped transparent tube (7x7 inches) with a yarn ball lodged in it (see Figure 4, p. 14). In these two more complex problems, the yarn balls were inaccessible with fingers so the children had to both choose and use the effective tools to retrieve the yarn balls (see Figures 3, p. 13, and 5, p. 14, or available tools).
MAJOR QUESTIONS OF INTEREST

From the overall experiment, in this study two sub-groups of children – “younger” (18-22 months-old) and “older” (27-36 months-old) – were chosen to compare their problem solving and strategy use for the 14-inch transparent tube problem, and the inverted transparent T-tube problem. The two sub-groups of children were chosen to compare responses and strategy use of children with almost a year age difference. Cognitive skills such as attention, language and memory, are rapidly developing at these ages and we would expect that these would enhance the problem solving abilities of the older children.

The two complex tube problems were chosen because they provided a means-end problem solving situation in a structure where monitoring the highly visible solution process would allow the children to self correct their actions until they reached the goal. The problems were based on physical actions the children needed to perform and were designed to generate visible behavior from which strategy use could be inferred. The purpose of the study was to investigate the following questions:

1. Can young children between the ages of 18-36 months solve the tube problems?
2. What general strategies do the younger (18-22 months old) versus the older (27-36 months old) children use in solving the tube problems?
3. Do the younger (18-22 months old) children’s strategies differ from the strategies of the older (27-36 months old) children when faced with the same spatial problems?
4. Would a verbal hint improve the problem solving of children who were not successful otherwise?
5. Would modeling or assisting improve the performance of children who were not successful otherwise?

HYPOTHESES

1. Younger (18-22 months old) children were expected to need support in the form of verbal hints or modeling more often than older (27-36 months old) children to be successful in solving the tube problems.
2. Older children were expected to use more cognitively complex strategies than younger children, in both problem solving situations.
3. The younger children were expected to use unsuccessful strategies more often than the older children. The older children were expected to use successful strategies more often than the younger children.
4. Verbal hint from the experimenter was expected to improve the success rate of some of the children who were not successful otherwise.
5. Modeling or assisting was expected to improve the success rate of some of the children who were not successful otherwise.

**PURPOSE OF THE STUDY**

The present study is of interest in the field of research on children’s problem solving, because of the age group examined and the methods used to explore young children’s thinking and problem solving.

The majority of existing research focusing on problem solving involved school age children (Bjorklund & Harnishfeger 1990; Deloache & Miller & Pierroutsakos 1998; Newell & Simon 1972; Shrager & Siegler, 1998; Siegler, 1995, 1996; Siegler & Crowley, 1994; Siegler & Jenkins, 1989; Wickelgren 1974). The present study included children between the ages of 18 to 36 months to investigate their spontaneous problem solving.

This study builds on the small number of studies that investigated the problem solving of infants and toddlers, but it differs from them in that it used a different method to reveal the strategies and competencies of this age group. Previous studies attempted to measure whether infants and toddlers were capable of learning problem solutions through numerous training sessions, and transferring the strategies that were first modeled to them (Chen, Sanchez, & Campbell, 1997; Chen & Siegler, 2000; Want & Harris, 2001). In the present study there were no initial modeling or training sessions, children had to devise their own strategies, transfer them to similar problems and develop new strategies as the tasks became more complex. Verbal hints and modeling were offered only when the children could not generate a successful strategy after several tries.

**THEORETICAL BASES**

Children’s thinking and problem solving change extensively with age. How these changes come about and how to best explain them is still under considerable debate.

One of the most influential child development theorists Jean Piaget explained cognitive development in terms of a child’s progress through a series of four developmental periods. He postulated that these periods (and stages within the periods) are universal, starting with the sensorimotor period (from birth to age 2), then the preoperational period (from age 2 to 7), then the concrete operational period (from age 7 to 11) and finally the formal operational period (from age 11 to 15).
Piaget’s (Gruber & Voneche, 1995) explanation of each period is extensive and complex. For the purpose of this study we examine only the key developmental features of the sensorimotor period, with particular attention to stage 6 (18-24 months) within this period, and the beginning of the preoperational period (2-7 years). Looking at the first period and the beginning of the second period serves several purposes for this problem solving study. These periods cover the age range of interest to this study. They also cover essential developmental features such as, goal directed behavior, the appearance of the symbolic function and the development of internal representations. These cognitive developments are essential to problem solving.

Flavell (1963) in his extensive review of Piaget’s theory summarized the developmental change during the sensorimotor period as follows: “the infant moves from a neonatal, reflex level of complete self-world undifferentiation to a relatively coherent organization of sensory-motor actions vis-à-vis his immediate environment (p. 86).” In the first month of development infants start to modify their inborn reflexes. One example of this is that they suck on different objects differently. In the next few months infants start to coordinate reflex actions that were originally separate (e.g. grasping and sucking). For example, they reflexively grasp objects and start to repeat movements that at first accidentally brought these objects to their mouths. From age 4 to 8 months infants start to repeat actions that accidentally produced an interesting event in their immediate environment. For example they would repeatedly pull on a cord that is attached to a rattle over and over again to reproduce the visual and sound effects. Children at this stage are on the verge of true goal directed behavior; however they still would only repeat actions that were produced first by chance. In the next stage of development from 8 to 12 months infants “set out to obtain a certain result, independent of the means he is going to employ: for example, obtaining an object that is out of reach or has just disappeared under a piece of cloth or a cushion” (Piaget & Inhelder, 1969, p. 10). From age 12 to 18 months infants start to actively experiment and their actions become more creative and goal directed. For example they would drop objects from different heights, just to see what happens. From age 18 to 24 months children start to form internal representations and start to combine actions internally to achieve their goals. In this last developmental stage of the sensorimotor period “the child becomes capable of finding new means not only by external or physical groping
but also by internalized combinations that culminate in sudden comprehension or insight” (Piaget & Inhelder, 1969, p. 11). For example, children at this age start to engage in deferred imitation (reproducing perceptually absent models from memory), symbolic or pretend play and become capable of deducing simple problem solutions internally. With this newly emerged capacity “to represent actions rather than simply to perform them, the sensory-motor period draws to a close and the child is ready for an analogous but even more extended and tortuous apprenticeship in the use of symbols” (Flavell, 1963, p. 121).

Piaget theorized that the most important development in the next, preoperational period (from age 2 to 7) is the growth of children’s representational ability. Representations are especially important in the process of solving problems. He distinguished between two types of internal representations, symbols and signs (Piaget & Inhelder, 1969). Symbols, at the beginning of the development of representations, often resemble the objects they represent (e.g., a piece of cloth representing a pillow in pretend play) and are intended mainly for personal use. Signs (e.g., words and numbers) on the other hand do not resemble the objects they represent, but are arbitrary. Signs are shared representations intended for communication. One of the crucial points Piaget makes in his explanation of children’s representational development is summarized by Flavell (1963) as follows: “It is not the acquisition of language which gives rise to the symbolic function. Quite the contrary, the symbolic function is a very general and basic acquisition which makes possible the acquisition of both private symbols and social signs” (p.151). Although language plays an enormous role in thinking Flavell continues “thought is nonetheless far from being a purely verbal affair, neither in its fully formed state nor, above all, in its developmental origins” (p.155). In Piaget’s view there are three main differences between preverbal and verbal patterns of thought. (1) Preverbal (sensori-motor) thought is tied to the speed of actions, while verbal thought is not, because through language it is possible to represent a chain of actions rapidly. (2) Preverbal adaptations are constrained by the immediate time and space while verbal thought is not, because language liberates thought from the immediate. (3) While preverbal thought “proceeds by means of successive acts, step by step, thought, particularly through language, can represent simultaneously all the elements of an organized structure” (Piaget & Inhelder, 1969, p. 86).
In Piaget’s theory cognition in infants and toddlers develops through their constant interaction with their environment and through adjusting their actions as they receive a variety of sensory information as a result of their actions. He based his theory on thousands of observations and experiments with children of different ages. His contribution to the understanding of cognitive development was important and motivated extensive research in the field. Some of this research with similar and new aims led to many additional discoveries of children’s thinking. Some research has also led to some conflicting findings to Piaget’s theory, especially in the area of when basic competencies develop and in the way they develop. New research methods to test infants’ competencies found that infants are more competent and at earlier ages than proposed by Piaget. Some researchers especially interested in cognitive change found Piaget’s explanation of cognitive change too general. According to Miller (2002) there are “no specific statements as to how sensorimotor thought becomes preoperational thought or how preoperational thought becomes operational thought” (p. 80).

According to recent research, one method that can reveal specific information about how cognitive change occurs is the microgenetic method. According to Siegler and Crowley (1991) this method of research involves “observations of individual children throughout the period of the change”, these observations need to be high density “relative to the rate of change within that period” and they need to include “intensive trial-by-trial analysis intended to infer the processes that gave rise to the change” (p. 606). According to Siegler and Alibali (2005) using the microgenetic method to study change in children’s problem solving revealed three consistent findings:

One is that change does not ordinarily involve a simple substitution of a more advanced problem-solving strategy for a less advanced one (Alibali, 1999; Kuhn, 1995; Siegler, 1995; Tunteler & Resign, 2002). Older, less adequate strategies continue to be used, often for prolonged periods of time, even after new, better strategies are generated…. Thus application of new ways of thinking tends to be halting and piecemeal, rather than sudden and complete. A second consistent finding is that children generally think about problems in multiple ways at any given time…. A third consistent finding is that innovations follow successes as well as failure. Failure is not necessary to motivate discoveries; children generate new approaches to solving problems when older approaches have been yielding correct solutions as well as when they have not. (p. 348)

To explain the research findings generated using the microgenetic method on how cognitive change occurs in children’s development Siegler (1996) introduced his overlapping waves
theory. Siegler (2000b) summarized his assumptions that lead to the development of his theory as follows:

(1) children typically use a variety of strategies and ways of thinking, rather than just a single one, to solve a given problem; (2) the diverse strategies and ways of thinking coexist over prolonged periods of time, not just during brief transition periods; (3) experience brings changes in relative reliance on existing strategies and ways of thinking, as well as introduction of more advanced approaches. (p. 28)

Figure 1 shows how the distribution of the use of multiple strategies changes over time.


According to another influential cognitive developmental theorist, Lev Vygotsky (1978) cognitive development takes place as a result of mutual interaction with people. He defined his concept of the zone of proximal development as the distance between the “actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers” (Vygotsky, 1978, p. 86). According to his theory children can perform on a higher level with adult guidance. In a problem solving situation, guidance may
be as minor as a prompt, hint or clue or, if it is perceived necessary, can be more involved, such as modeling, discussion or joint participation.
CHAPTER 2

REVIEW OF LITERATURE

DEVELOPMENT OF PROBLEM SOLVING

According to Deloache et al. (1998), the development of children’s problem solving is based on the changes that take place in four main areas: changes in “solution strategies”, changes in “the resources” available for problem solving, changes in the “ability to plan and manage the solution process” and changes in the “social contexts in which problem solving occurs” (p. 827).

PROBLEM SOLVING STRATEGIES OVERVIEW

According to Deloache et al. (1998) a problem-solving situation consists of:

- a goal, one or more obstacles that make achieving the goal not immediately possible, one or (typically) more strategies that can be used to solve the problem, other resources (knowledge, other people, etc.) that can affect which strategies are used, and evaluation of the outcome of the problem solving process. (p. 826)

Problem solving strategies can be classified into two major categories: knowledge-intensive and knowledge-lean strategies (Newell, 1990).

Knowledge-intensive problem solving strategies are domain specific, while knowledge-lean methods are across domains. Being familiar with a certain domain, or having well-organized domain specific knowledge greatly increases the problem solving performance of children as well as adults. “Chi (1978) demonstrated that child chess experts outperformed psychology graduate students in a chess recall task, but showed the expected poorer performance on a digit span task” (Deloache et al., 1998, p.831). There are many reasons why content knowledge improves problem solving strategies of children. It helps children focus their attention on distinctive features of the problem. It aids all aspects of memory and improves the efficiency of acquisition and execution of strategies.

Knowledge-lean methods can be classified into three main categories – trial and error, hill climbing, and means-end analysis - depending on the cognitive complexity they impose on the solver (Wickelgren, 1974). The least complex problem solving strategy is trial-and-
error. It entails trying all possible strategies while monitoring whether the goal is achieved. Hill-climbing is a more complicated problem solving strategy. It requires the problem solver to choose strategies that move them closer to the goal, like climbing a hill, however it does not require the solver to envision the entire path leading to the goal. An even more complex strategy is means-end analysis, which requires the problem solver to evaluate the difference between the problem situation and the goal, and reason backward from the goal, setting subgoals to get closer to the goal (Newell & Simon, 1972). Means–end problem solving is difficult “because of the cognitive load imposed by generating, ordering, and remembering subgoals, and then using these goals to regulate problem solving” (Deloache et al., 1998, p. 827). However, failure to carry out a means-end action sequence may not necessarily mean the absence of this problem solving ability, it can reflect “an inability to think of the relevant solution procedure” in which case “a hint concerning the proper procedure should be effective in improving performance (Ross, 1989)” (Deloache et al., 1998, p. 827). Also, previous studies have shown that verbal hints and modeling of the action sequence children needed to perform in a given task helped the children in achieving their goals (Chen et al., 1997; Chen & Siegler, 2000; Want & Harris, 2001). The structure of the present study invites means-end problem solving, but all three problem solving strategies may be observed.

The majority of the research that has focused on children’s problem solving studied school-aged children who could comment on and describe their thought processes (Bjorklund & Harnishfeger 1990; Deloache et al., 1998; Newell & Simon 1972; Shrager & Siegler, 1998; Siegler, 1995, 1996; Siegler & Crowley, 1994; Siegler & Jenkins, 1989; Wickelgren, 1974). In these experiments children were given a problem (most often in the area of math and science), and were asked to comment on each step as they were solving the different components of the problems. This method was proven to be useful in studying the development of problem solving strategies of this age group. However to study the problem solving of very young children who cannot reflect on their own thinking or explain their own actions requires a different experimental design.

Studies that involved very young children (infants and toddlers) mainly relied on imitation and transfer of learned strategies to solve problems. These problems were based on physical actions the children could perform and were designed to generate visible behavior. In these studies the children were usually shown the right solution process and were tested on
the same and similarly structured problems. Chen et al. (1997) demonstrated in a series of experiments that “1-year-olds can transfer a solution strategy learned through observation and imitation of modeled actions to novel problems with similar structures but different surface features” (p. 798). The tasks in these experiments “were designed to examine whether modeling would facilitate problem-solving performance on target tasks that required more than a simple reproduction of the modeled actions. Infants proved able to modify the acquired solutions in analogous but novel situations” (p. 800).

A study by Chen and Siegler (2000) showed that some research methods developed to study the cognitive development of older children, such as the microgenetic method (Kuhn, 1995) is also applicable to study the learning and problem solving of toddlers. In this study the children received a hint or a demonstration on how to obtain an out of reach toy. Through detailed componential analysis (acquisition of new strategy, mapping of the strategy onto structurally similar problems, strengthening of the strategy, refining of the strategy, and strategy execution) the researchers found improvement in all five components of these learning processes after both the hint and the modeling conditions.

A study by Want and Harris (2001) showed that when 2- and 3-year-old children were shown a correct solution to a tool-using task they all produced at least a partial solution. When the children were shown an incorrect solution followed by a correct solution, 2-year-olds produced only a partial solution but most 3-year-olds produced a full solution. Their study indicates “that by 3 years of age children do not indiscriminately imitate actions on a tool but selectively reproduce those actions that have a desired causal effect” (p. 431).
CHAPTER 3

METHOD

PARTICIPANTS

The study involved 41 children (n = 41) between the ages of 18-36 months old who were recruited through advertisements in local publications and local day care centers. All children were tested and videotaped at the Developmental Psychology Laboratory at San Diego State University with a parent present throughout the study.

Of the 41 children, 28 were chosen for the present study, age being the sole criterion for the selection. The children were divided into a younger age group, age 18-22-months (n = 15; mean age = 20 months) and an older age group, age 27-36-months (n= 13; mean age = 31.5 months).

EXPERIMENTAL DESIGN

The performance of the children in the younger and older group was compared for two separate problem-solving tasks. In both experiments, the children were presented with a plastic tube with a yarn ball lodged inside and a tray of tools to use to dislodge the yarn ball. Each tray contained effective and ineffective tools. An effective tool was the correct length and diameter to dislodge the yarn ball, and an ineffective tool was either the wrong diameter or shape. The ability of each child to dislodge the yarn ball was measured in various ways.

One of the problem solving tasks was to dislodge a colored yarn ball from a 14-inch long transparent plastic tube (see Figure 2), by choosing and using the two correct tools simultaneously (correct length and diameter) from a tray that also contained three ineffective tools (correct length but incorrect diameter or shape) (see Figure 3).

The only way for a child to succeed in retrieving the yarn ball from the 14-inch long tube was to choose both of the effective tools from the tray of tools, insert them into the same side of the tube and push the yarn ball out completely, or close enough to the edge of the tube that it could be reached by fingers.
Figure 2. 14-inch long transparent plastic tube with colored yarn ball.

Figure 3. Tray of tools provided for 14-inch tube problem. Tools from left to right: Effective, ineffective, effective, ineffective, ineffective.
The other task was to dislodge a colored yarn ball from an inverted T shaped transparent plastic tube (see Figure 4), by choosing and using the one correct tool (correct length and diameter) from a tray that also contained three ineffective tools (correct length, incorrect diameter or shape) (see Figure 5).

Figure 4. Inverted T shaped transparent plastic tube with colored yarn ball.

Figure 5. Tray of tools provided for inverted T-tube problem. Tools from left to right: Effective, ineffective, ineffective, ineffective.
The only way for a child to succeed in retrieving the yarn ball from the inverted T-tube was first to choose the correct tool from the tray, then use the tool to push the yarn ball down from the vertical section into the horizontal section of the tube.

Then retrieve the tool and insert it into the horizontal section and push the yarn ball out, or close enough to the edge of the tube that it could be reached by fingers.

Some of the children needed help from the experimenter to successfully solve these problems. Help was categorized into: verbal help and modeling or assisting. First, if the child was unable to produce a successful strategy in a given time (approximately 1-2 minutes), the experimenter provided an appropriate verbal hint. If the child did not respond to the verbal hint, the experimenter would assist with or model the next step in the action sequence the child needed to perform.

Verbal help was always offered first. Examples of verbal help given by the experimenter were: “Can you use something to get the ball out?” or “How about one of these?” pointing to the tray of tools, or “Try using another stick.” or in the 14-inch tube problem “Can you use two sticks?” If verbal help was given to the child during problem solving it was recorded as “1” if not, it was recorded as “0”.

Assistance was offered to the child after verbal help was observed to be insufficient. Examples of assistance were: handing the correct tool to the child, inserting the correct tool into the tube, or modeling an action the child needed to perform. Assistance or modeling help was offered to the children indiscriminately throughout the trials and were recorded as “1” if help was given or “0” if not.

The unsuccessful strategies a child exhibited when trying to retrieve the yarn ball from a tube were grouped into three categories: finger strategy, tool strategy, social strategy. The number of unsuccessful strategies used by a child while trying to retrieve the yarn ball was tabulated in each trial. By measuring the unsuccessful strategies we hoped to see if there was any unsuccessful strategy that was used more often than any other in each age group during problem solving.

An unsuccessful strategy was coded as “finger strategy” if a child tried to use their fingers as tools to retrieve the yarn balls. This would be evaluated as an ineffective strategy because the yarn balls were deeply seated in the clear plastic tubes and were not accessible to
their fingers. If a child used their fingers in an attempt to retrieve the yarn ball, it was recorded as “1” if not, it was recorded as “0”

An unsuccessful strategy was coded as “tool strategy” if a child tried to use any of the ineffective tools that would not result in successful retrieval of the yarn ball. Also in this category were situations where a child chose the correct tool or tools, but did not perform the correct combined actions with them to retrieve the yarn ball. For the 14-inch tube trial, examples of tool strategy errors using the correct tool were: 1. repeatedly pushing only one of the correct tools into the tube which would not push the yarn ball into reach, 2. inserting the second correct tool into the opposite side of where the first tool was inserted therefore trapping the yarn ball in the middle. For the inverted T-tube trial, a tool strategy error using the correct tool was: inserting the correct tool into the portion of the tube that did not contain the yarn ball. This meant either repeatedly pushing the correct tool into the horizontal section of the tube while the ball was in the vertical section or repeatedly pushing the correct tool into the vertical section of the tube while the ball was already pushed into the horizontal section. If an unsuccessful tool strategy was used by the child, it was recorded as “1” if not, it was recorded as “0”.

An unsuccessful strategy was coded as “social strategy” when a child directly or indirectly tried to get the experimenter or parent to help retrieve the yarn balls. Examples of social strategies were: a child hands a tool to an adult for help, a child looks, asks or gestures to an adult in expectation of help. If a child used a social strategy, it was recorded as “1” if not, it was recorded as “0”.

**RESPONSE SCORING**

Data were transcribed and scored from videotapes recorded during problem solving. A coding form was developed to record the problem solving strategies of the children (see Appendix). Variables measured on both tube problems were:

1. The age group of the child (younger: 18-22 months, or older: 27-36 months).
2. The child’s overall success or failure in retrieving the yarn ball.
3. Condition of success in retrieving the yarn ball (success without help or success with help).
4. The type of help a child received before they were able to retrieve the yarn ball (verbal help or modeling).
5. The type of unsuccessful strategies (finger strategy, tool strategy, social strategy) used by the child.
6. The number of unsuccessful strategies used by the child (0, 1, 2, or 3).

**DATA ANALYSIS**

The data were entered and stored in MS Excel. Descriptive statistics such as averages, frequency counts and cross tabulations were calculated. The Fisher Exact test was used to compare the performance of the two age groups on each tube problem with the hypotheses that older children would have significantly greater success than younger children. The following were analyzed for each tube problem and age group:

1. Success or failure in retrieving the yarn ball.
2. Condition of success in retrieving the yarn ball (success without help or success with help).
3. The type of help a child received before they were able to retrieve the yarn ball (verbal help or modeling).
4. The type of unsuccessful strategies (finger strategy, tool strategy, social strategy) used by the child.
5. The number of unsuccessful strategies used by the child (0, 1, 2, or 3).
CHAPTER 4

RESULTS

Of the 28 children participating in this study, four had to be disqualified because of non-compliance or too much interference from the parent throughout the trials. The final sample included 24 children, 11 in the younger age group 18-22 months-of-age (n = 11; mean age = 20 months) and 13 in the older age group 27-36 months-of-age (n = 13; mean age = 31.5 months).

14-INCH TUBE PROBLEM

In this section the success rates, conditions of success, and the type and number of unsuccessful strategies used by the two groups of children on this problem were examined and compared.

The success rate of solving the 14-inch tube problem was high for both groups. Examination of percentages by age revealed that 72.7% of the children in the younger age group and 92.3% of the children in the older age were successful, while 27.3% in the younger age group and 7.7% in the older age group were unsuccessful solving this problem (see Table 1 and Figure 6). There was no significant difference between the younger and the older age group’s performance (p = 0.300).

Table 1. Success Rate of Children for the 14-Inch Tube Problem

<table>
<thead>
<tr>
<th>Age group</th>
<th>Success (%)</th>
<th>No success (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-22 months</td>
<td>72.7</td>
<td>27.3</td>
</tr>
<tr>
<td>27-36 months</td>
<td>92.3</td>
<td>7.7</td>
</tr>
</tbody>
</table>

Examination of percentages by age of the children who succeeded on the trial revealed that 25% of the children in the younger age group and 50% of the children in older age group solved the problem without help. While 75% of the younger age group and 50% of the older age group solved the problem with the help of the experimenter (see Table 2 and...
Figure 6. Success rate of children for the 14-inch tube problem.

Table 2. Condition of Success for the 14-Inch Tube Problem

<table>
<thead>
<tr>
<th>Age group</th>
<th>Success without help (%)</th>
<th>Success with help (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-22 months</td>
<td>25.0</td>
<td>75.0</td>
</tr>
<tr>
<td>27-36 months</td>
<td>50.0</td>
<td>50.0</td>
</tr>
</tbody>
</table>

Figure 7). There was no significant difference between the younger and the older age group’s performance ($p = 0.373$).

Examination of percentages of those children who succeeded with help from the experimenter revealed that 50% of the children in the younger age group and 100% of the children in older age group solved the problem with verbal help.

None of the children in the older age group needed modeling help and 50% of the children in the younger age group solved the problem with modeling help (see Table 3 and Figure 8). There was no significant difference between the younger and the older age group’s performance ($p = 0.182$)

There were 3 types of unsuccessful strategies the children used on this trial: finger, tool, and social strategy. The results of the examination of percentages by age and type of unsuccessful strategies the children used are shown in Table 4 and Figure 9. There was no significant difference between the younger and the older age group’s strategy use ($p = 1.000$).
Figure 7. Condition of success for the 14-inch tube problem.

Table 3. Type of Help Given to Children who Succeeded with Help for the 14-Inch Tube Problem

<table>
<thead>
<tr>
<th>Age group</th>
<th>Verbal help (%)</th>
<th>Modeling help (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-22 months</td>
<td>50.0</td>
<td>50.0</td>
</tr>
<tr>
<td>27-36 months</td>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 8. Type of help given to children who succeeded with help for the 14-inch tube problem.
Table 4. Unsuccessful Strategies Used by All Children for the 14-Inch Tube Problem

<table>
<thead>
<tr>
<th>Age group</th>
<th>Finger (%)</th>
<th>Tool (%)</th>
<th>Social (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-22 months</td>
<td>81.8</td>
<td>81.8</td>
<td>27.3</td>
</tr>
<tr>
<td>27-36 months</td>
<td>84.6</td>
<td>84.6</td>
<td>38.5</td>
</tr>
</tbody>
</table>

None of the younger children could succeed in this trial without using at least one unsuccessful strategy. In the older age group some children (7.7%) succeeded without using any unsuccessful strategy. More children in the younger age group (27.3%) than in the older age group (7.7%) used at least one unsuccessful strategy before succeeding. It was most common to use two unsuccessful strategies for both the younger (54.6%) and the older (53.8%) groups. Fewer children in the younger age group (18.2%) than in the older age group (30.8%) used three unsuccessful strategy before they succeeded. These results are also shown in Table 5 and Figure 10. There was no significant difference between the younger and the older age group’s unsuccessful strategy use.

None of the younger children who succeeded without any help could succeed without using some unsuccessful strategy. Half of the younger children (50%) used at least one unsuccessful strategy, the other half (50%) used two unsuccessful strategies. In the older age group some children (16.6%) succeeded without using any unsuccessful strategy, some (16.6%) used one, some (16.6%) used three, but it was most common to use two unsuccessful strategies (53.8%) before they succeeded with the task. These results are also
Table 5. Number of Unsuccessful Strategies Used by All Children for the 14-Inch Tube Problem

<table>
<thead>
<tr>
<th>Age group</th>
<th>0 Unsuccessful (%)</th>
<th>1 Unsuccessful (%)</th>
<th>2 Unsuccessful (%)</th>
<th>3 Unsuccessful (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-22 months</td>
<td>0.0</td>
<td>27.3</td>
<td>54.6</td>
<td>18.2</td>
</tr>
<tr>
<td>27-36 months</td>
<td>7.7</td>
<td>7.7</td>
<td>53.8</td>
<td>30.8</td>
</tr>
</tbody>
</table>

Figure 10. Number of unsuccessful strategies used by all children for the 14-inch tube problem.

shown in Table 6 and Figure 11. There was no significant difference between the younger and the older age group’s unsuccessful strategy use.

**INVERTED T-TUBE PROBLEM**

In this section the success rates, conditions of success, and the type and number of unsuccessful strategies used by the two groups of children on the inverted T-tube problem are examined and compared.

The success rate of solving the inverted T-tube problem was high for both groups. Examination of percentages by age revealed that in the trial involving the inverted T-tube, 90.9% of the younger age group and 100% of the older age group was successful. Only 9.1% of the children in the younger age group were unsuccessful in solving this problem (see
Table 6. Number of Unsuccessful Strategies Used by Independently Successful Children for the 14-Inch Tube Problem

<table>
<thead>
<tr>
<th>Age group</th>
<th>0 Unsuccessful (%)</th>
<th>1 Unsuccessful (%)</th>
<th>2 Unsuccessful (%)</th>
<th>3 Unsuccessful (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-22 months</td>
<td>0.0</td>
<td>50</td>
<td>50</td>
<td>0.0</td>
</tr>
<tr>
<td>27-36 months</td>
<td>16.6</td>
<td>16.6</td>
<td>50</td>
<td>16.6</td>
</tr>
</tbody>
</table>

Figure 11. Number of unsuccessful strategies used by independently successful children for the 14-inch tube problem.

Table 7 and Figure 12). There was no significant difference between the younger and the older age group’s performance (p = 0.458).

There was an inverse relationship between age and condition of success. In the younger age group 20% of the children solved the problem without help, and 80% solved the problem with the help of the experimenter. Of the older age group, 84.6% of the children solved the problem without help and 15.4% solved the problem with help from the experimenter (see Table 8 and Figure 13). There was a significant difference between the younger and the older age group’s performance (p = 0.003).
Table 7. Success Rate of Children for the Inverted T-Tube Problem

<table>
<thead>
<tr>
<th>Age group</th>
<th>Success (%)</th>
<th>No success (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-22 months</td>
<td>90.9</td>
<td>9.1</td>
</tr>
<tr>
<td>27-36 months</td>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>

![Bar chart showing success rate of children with the inverted T-tube problem]

Figure 12. Success rate of children with the inverted T-tube problem

Table 8. Condition of Success for the Inverted T-Tube Problem

<table>
<thead>
<tr>
<th>Age group</th>
<th>Success without help (%)</th>
<th>Success with help (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-22 months</td>
<td>20.0</td>
<td>80.0</td>
</tr>
<tr>
<td>27-36 months</td>
<td>84.6</td>
<td>15.4</td>
</tr>
</tbody>
</table>

Table 9 further analyzes the group of children who achieved success with help and shows the distribution of verbal and modeling help in this task. The analyses of successful strategies show that some of the children (25%) in the younger age group and all of the children (100%) in the older age group could solve the problem after receiving a verbal hint from the experimenter. In the younger age group, 75% could solve the problem after receiving modeling help and in the older age group, none of the children needed modeling help (see Table 9 and Figure 14). Fisher’s exact test revealed no significant difference between the younger and the older age group’s performance ($p = 0.133$).
Figure 13. Condition of success for the inverted T-tube problem.

Table 9. Type of Help Given to Children who Needed Help to Succeed for the Inverted T-Tube Problem

<table>
<thead>
<tr>
<th>Age group</th>
<th>Verbal help (%)</th>
<th>Modeling help (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-22 months</td>
<td>25.0</td>
<td>75.0</td>
</tr>
<tr>
<td>27-36 months</td>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 14. Type of help given to children who needed help to succeed with the inverted T-tube problem.
Unsuccessful strategies were again categorized into finger, tool and social strategies. The results of the examination of percentages by age and type of unsuccessful strategies used on the trial are shown in Table 10 and Figure 15. There was no significant difference between the younger and the older age group’s unsuccessful strategy use.

**Table 10. Unsuccessful Strategies Used by All Children for the Inverted T-Tube Problem**

<table>
<thead>
<tr>
<th>Age group</th>
<th>Finger (%)</th>
<th>Tool (%)</th>
<th>Social (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-22 months</td>
<td>90.9</td>
<td>54.5</td>
<td>63.6</td>
</tr>
<tr>
<td>27-36 months</td>
<td>38.5</td>
<td>23.1</td>
<td>15.4</td>
</tr>
</tbody>
</table>

**Figure 15. Unsuccessful strategies used by all children with the inverted T-tube problem.**

Examination of percentages of unsuccessful strategies used by the different age groups in the inverted T-tube trial revealed an inverse relationship between age and number of unsuccessful strategy used. About half of the children (45.5%) of the younger age group used three unsuccessful strategies and only 9.1% could solve this problem without using any unsuccessful strategy. In contrast none of the children in the older age group needed to use as many as three unsuccessful strategies and about half the children (46.2%) could solve the problem without using any unsuccessful strategies (see Table 11 and Figure 16). Fisher’s exact test revealed a significant difference between the younger and the older age group’s
Table 11. Number of Unsuccessful Strategies Used by All Children for the Inverted T-Tube Problem

<table>
<thead>
<tr>
<th>Age group</th>
<th>0 Unsuccessful (%)</th>
<th>1 Unsuccessful (%)</th>
<th>2 Unsuccessful (%)</th>
<th>3 Unsuccessful (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-22 months</td>
<td>9.1</td>
<td>18.2</td>
<td>27.3</td>
<td>45.5</td>
</tr>
<tr>
<td>27-36 months</td>
<td>46.2</td>
<td>30.8</td>
<td>23.1</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 16. Number of unsuccessful strategies used by all children in the inverted T-tube problem.

performance in regard of not using any unsuccessful strategies and using as many as three unsuccessful strategies during problem solving (p = 0.015).

Half of the younger children (50%) did not use any unsuccessful strategies while solving this problem, the other half (50%) used two unsuccessful strategies. For the older age group about half of the children (55%) did not use any unsuccessful strategies, some used one (27%) and some used two (18%), but none needed to use as many as three unsuccessful strategies while solving this problem (see Table 12 and Figure 17.). Fisher’s exact test revealed no significant difference between the younger and the older age group’s performance in regard to the number of unsuccessful strategies used by independently successful children.
Table 12. Number of Unsuccessful Strategies Used by Independently Successful Children for Inverted T-Tube Problem

<table>
<thead>
<tr>
<th>Age group</th>
<th>0 Unsuccessful (%)</th>
<th>1 Unsuccessful (%)</th>
<th>2 Unsuccessful (%)</th>
<th>3 Unsuccessful (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-22 months</td>
<td>50.0</td>
<td>0.0</td>
<td>50.0</td>
<td>0.0</td>
</tr>
<tr>
<td>27-36 months</td>
<td>55.0</td>
<td>27.0</td>
<td>18.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Figure 17. Number of unsuccessful strategies used by independently successful children on the inverted T-tube problem.
CHAPTER 5

DISCUSSION AND RECOMMENDATIONS

The purpose of this study was to investigate and compare the problem solving and strategy use of 18 to 22 months old and 27 to 36 months old children on two problem solving tasks. Possible explanations for the results could provide insight into developmental similarities and differences in problem solving and strategy use of these age groups. Limitations of the study and recommendations for future research will be discussed.

CONDITION OF SUCCESS

Most children in the younger age group and almost all the children in the older age group were able to devise effective strategies to solve both tube problems. The main difference between the two age groups was the way they succeeded with the tasks. Most children in the older age group were able to solve the T-tube problem without help, and those children who needed help were able to succeed after receiving a verbal hint. In contrast most children in the younger age group were not able to succeed without help and in most cases verbal help was not enough, they needed modeling help. In the case of the 14-inch tube problem there was no significant difference in the condition of success between the two age groups. The 14-inch tube problem seemed to offer more of a challenge to both groups. One possible explanation is that the children could not be successful using just one tool as they could in the inverted T-tube problem. In the 14-inch tube problem, the children needed to use a second tool and this added another step and more complexity to the process. With this more complex problem, the older age group’s responses and results were more similar to the younger age groups’ in most aspect except one. While some of the younger children needed modeling help, none of the children in the older age group needed modeling help to be successful.

Planning, monitoring and correcting a solution process to a given problem can be difficult for young children. The results show that some of the older children could manage these difficulties and solve the problems without help. Providing some form of assistance to those children who could not manage otherwise, helped to separate children who could
comprehend the problems from those who could not. A child who truly does not comprehend the problems will not likely benefit from verbal prompts or from assistance with a sub-goal. The results confirmed this expectation. There were some children in both age groups who were not successful even after they received verbal and modeling help.

Helping young children in problem solving situations is common practice in everyday life. Also, previous studies involving 12 to 18 months old (Chen, et al., 1997, Goubet, Rochat, Maire-Leblond & Poss, 2006) and 2-3 year old children (Chen & Siegler, 2000; Want & Harris, 2001) have shown that verbal hints and modeling of the action sequence children needed to perform aided their performance in problem solving situations. These studies included training sessions of either telling the children or showing the children the correct actions or action sequence they needed to perform. During these training sessions children learned to imitate actions that were modeled to them. These trainings reduced the strategic variability and increased the likelihood that the children would use the learned strategies. The current study did not include training sessions; instead the children received the least amount of help they needed to help their problem solving efforts. This approach gave more opportunities to the children to try to solve the problems with mostly their own efforts. Verbal and modeling help was offered to those children who were not successful otherwise. The difficulty of means–end problem solving (as these tasks presented) is often caused by the cognitive overload of generating, ordering, and remembering sub-goals (Deloache et al., 1998). The purpose of the help was to ease the cognitive load and help children move forward with their problem solving efforts. The results showed that for those children who needed help solving the problems in the older age group (27-36 months) verbal hints were always sufficient enough to aid their efforts in both problems. None of the older children needed modeling to succeed. These results suggest that by age 3 verbal hints can be an effective way to help children in problem solving situations. In the younger age group (18-22 months) those children who needed help to succeed benefitted more from modeling help than from verbal hints. As previously discussed, Piaget states that one of the most important developments that occurs in the thinking of children between the ages of 18 to 36 months is the growth of representational ability (Piaget & Inhelder, 1969). Since the younger age group consisted of children ages 18 to 22 months, it was expected that children in this age group would have more limited representational skills and would benefit more from modeling than
from verbal hints. The results confirmed this expectation. Although some of the younger children could represent the required actions and solved the problems without modeling, many could not. Most children in the younger age group needed modeling (a physical representation) to be able to form their own mental representation and be successful with the tasks. The results of the study shows that even very young children can be successful solving problems with some adult guidance. The results suggest that by age three verbal hints can be an effective way to help children in problem solving situations, but for children younger than two years old modeling is more effective.

**Specific Strategy Use**

The results of the study show that children between the ages of 18 to 36 months used multiple strategies in a problem solving situation. According to Gopnik (2011), there are four different models to explain how children learn and represent causality. The children’s strategy use in the current study suggests correspondence with two of these models: agency and the probability models. Agency emphasizes children’s interaction with the environment. The probability model emphasizes inferences about possibilities and testing hypotheses as ways to learn and represent causality. The results of this study suggest that those children who were successful without using any unsuccessful strategies during problem solving had the correct hypothesis about what to do to succeed without any interaction with the problems. Those children who succeeded after using several unsuccessful strategies were most likely testing and trying out possible hypotheses and needed to interact with the problems to succeed. The unsuccessful strategies the children used did not seem like random guesses but instead were reasonable strategies that might have worked before in similar problem solving situations.

Previous studies of preschool and elementary school aged children showed that when children have enough understanding of the goals and causal relationships in a problem they generate a goal sketch (Siegler, 2000a, 2000b; Siegler & Crowley, 1994, Siegler & Jenkins, 1989). This goal sketch helps them choose a strategy from already existing strategies that might be effective in a new situation, or it can help them generate reasonable new strategies. The goal in the present problems was getting a yarn ball out of clear tubes. The children’s choices of the strategies in general (finger, tool, social), suggest that they had an
understanding of the goals and the strategies needed to achieve the goals. Even though the finger strategy would not lead to success in the current problems, this strategy was a reasonable attempt in trying to retrieve the balls from the tubes. This basic strategy might have worked in previous situations the children encountered when they were trying to retrieve an object that was stuck in another object. Moreover this strategy was strengthened as a successful one during the initial trials with the shorter tubes, where they could reach the yarn balls with their fingers. Asking for help was also a reasonable strategy children might have had success with in other situations where they encountered difficulty in obtaining their goals. According to Mosier and Rogoff (1994) infants often use their mothers to achieve their goals. Trying to use different tools to get to something they could not reach with their fingers was also a reasonable strategy they might have encountered before and in our case it was the only strategy that led to success. All of the above suggests that some children as young 18 to 22 months old and most 27 to 36 months old, who used the above strategies can successfully generate a goal sketch, which then helped them generate possible strategies relevant to the goal they were trying to achieve. This finding corresponds with what has been observed in the problem solving of older children.

By examining the type of unsuccessful strategies the children used we also wanted to see whether there were any strategies that were used more often than any other in each age group during problem solving. The results showed no single most commonly used strategy during problem solving in either of the age groups. The children used a variety of strategies in both problems. This result corresponds with one of the main tenets of Siegler’s (1996) overlapping waves theory that postulates that children usually use a variety of strategies during problem solving.

**OVERALL STRATEGY USE**

Although there was no significant difference in the types of basic strategies (finger, tool, social) the children used during problem solving, there was a significant difference between the number of different strategies the two age group used before they succeeded with the tasks. Analyzing the ratio of successful and unsuccessful strategies as well as comparing the number of unsuccessful strategies the children used during problem solving can give us more insight into developmental similarities and differences in strategy use.
Solving the problems without using any unsuccessful strategies would indicate that a child used means-end analysis by reasoning backward from the goal, creating and executing sub-goals that helped them attain the solution. Many of the older children but only a few of the younger children succeeded this way. Not using any unsuccessful strategies indicates that children who succeeded this way may have mentally represented and evaluated the strategies before they used them. As we discussed previously in Piaget’s theory verbal thought can represent an organized structure (Piaget & Inhelder, 1969). Because language plays an important role in mental representation, by having better language skills older children are more flexible in mental representation. The results indicate that means-end problem solving is more prevalent and was used more frequently in the older age group (27-36 months) than in the younger age group (18-22 months).

Using one or two unsuccessful strategies would indicate that a child used the less sophisticated hill-climbing strategy, which does not require the solver to predict the whole path to a solution, but to reason forward in the direction of the goal. In the case of the inverted T-tube problem, about half of the children in both age groups succeeded this way. In the 14-inch tube problem this was the most common way to succeed for both age groups. There was no significant difference between the two age groups in regards of using the hill-climbing strategy. These results indicate that the hill-climbing strategy is prevalent in both age groups and is used frequently during problem solving.

Using three unsuccessful strategies during problem solving would indicate that a child used the least sophisticated trial and error strategy, trying all possibilities until one worked. In the case of the inverted T-tube problem about half of the younger children succeeded this way, but none of the older children used as many as three unsuccessful strategies. In the case of the 14-inch tube problem some of the children in both age groups used three unsuccessful strategies before succeeding. These results indicate that trial and error strategy is used by both age groups but it is a more prevalent strategy in the younger age group.

**IMPLICATIONS OF THE STUDY**

The practical implications of this study and its theoretical base are important for parents and teachers of young children. The study shows that very young children are active
problem solvers and use many different strategies in problem solving situations. As previously discussed in Piaget’s theory (Piaget & Inhelder, 1969), cognition in infants and toddlers develops through their constant interaction with their environment and through adjusting their actions as they receive a variety of sensory information as a result of their actions. Parents and teachers can aid the development of children’s thinking by providing a wide variety of age appropriate problem solving opportunities.

According to Siegler and Alibali (2005), children’s thinking changes during problem solving. Children actively experiment in problem solving situations and learn from their successes as well as from their failures. Parents and teachers should actively encourage and let young children solve problems they are capable of solving. Problem solving can facilitate children’s construction of knowledge as they manipulate objects, think of or act out possibilities or perceived possibilities and interpret the information that comes from their active involvement with a problem. Problem solving helps children’s decision making skills and can support autonomy, as well as collaboration.

According to Vygotsky (1978) children can perform on a higher level with adult guidance which may be as minor as a hint or a clue or more involved such as modeling, discussion, or joint participation. In situations where children are not successful with their problem solving efforts, adults could support them with the minimum amount of help they would need to succeed. The results of the study suggest that by age three verbal hints can be an effective way to help children in problem solving situations, but for children younger than two years old modeling is more effective. The challenge for parents and teachers of young children is finding out where each child is in their development, encourage them to solve developmentally appropriate problems independently and if needed, provide just the right amount of scaffolding at the right time to enable them to advance beyond their current skill level.

The implications of the study may be extended to support developmentally appropriate early childhood education practices. The National Association for the Education of Young Children (NAEYC) supports high quality early childhood education practices. Their position statement on developmentally appropriate practices in early childhood programs (NAEYC, 2009) states that such a practice requires “meeting children where they are -which means that teachers must get to know them well- and enable them to reach goals
that are both challenging and achievable” (NAEYC, 2009, p. xii). One of the ways this goal can be achieved by teachers is through encouraging children to solve developmentally appropriate, but challenging problems and scaffold the children’s efforts when it is necessary. The position statement also states that a developmentally appropriate practice in early childhood programs “does not mean making things easier for children. Rather, it means ensuring that goals and experiences are suited to their learning and development and challenging enough to promote their progress and interest” (NAEYC, 2009, p. xii). The findings and implications of the current study suggest that problem solving is a valuable and developmentally appropriate activity to be included in any high quality preschool curriculum.

**LIMITATIONS AND RECOMMENDATION FOR FUTURE RESEARCH**

The major limitation of this research was the small sample size. Every effort was made to recruit a larger group of children and increase the number of participants. With a larger sample size the study would have more power to detect possible differences. Also, the children who participated in the study were recruited through advertisements in local newspapers and local day care centers. The parents who answered these advertisements and took the time and effort to bring their children to the university to participate in the study certainly showed an active interest in their children’s cognitive development. It is a possibility that these parents may have involved their children in activities that enhanced these children’s cognitive development above other children’s whose parents do not take such an active role. These variables may impact the generality of the findings of the study.

More studies are needed to explore young children’s problem solving. Involving wider age ranges, larger sample sizes and implementing more diverse tasks would help us further explore young children’s thinking and problem solving. Involving a wider age range of children would help us gain a better understanding of how the representational abilities of young children change with age. Also, because language plays an important role in mental representations, collecting data about the children’s verbal abilities could provide further insights. Larger sample sizes of more continuous age groups would increase the possible generality of the findings. Also, with larger sample sizes it would be possible to determine whether there are gender differences in problem solving and strategy use across the age groups. In future research more piloting of tool tasks is recommended to attain higher
variability of the results than were observed in the current study. Implementing more diverse tasks with increasing difficulty would give children more opportunities to interact with problems. Analyzing the children’s interaction could provide additional information on how the strategies of different age groups change with experience.

Problem solving is a valuable and developmentally appropriate activity for young children. Future studies could focus on independent as well as scaffolded problem solving of toddlers and preschoolers. The most useful scaffolding practices could be examined, for different age groups and for different kind of problems. Also, in future research, testing young children in their home environment, rather than in a cognitive developmental laboratory could be considered.

**SUMMARY**

The current study examined and compared the problem solving of 18 to 22 and 27 to 36 months old children. These age groups are not commonly studied in this aspect because very young children cannot reflect on their own thinking or tell us about their problem solving strategies. Analyzing the specific strategies the children used during problem solving gave us insight about the similarities and differences in the overall strategy use of the age groups. Significantly more children in the older age group succeeded independently and by using means-end analysis. Both groups of children used the hill-climbing strategy with similar frequency, but significantly more children in the younger age group used trial and error strategy during problem solving. The children’s strategy choices in general suggested that they had an understanding of the goals of the problems and the strategies needed to achieve these goals. The results of the study correspond with the overlapping waves theory (Siegler, 1996) that postulates cognitive variability in children’s thinking and problem solving. Scaffolding (e.g. verbal hint or modeling) was offered to children who were not successful independently. The results showed that verbal hints were always sufficient help for the older children, but were less sufficient for the younger children, who often needed modeling to succeed.

The practical implications of this study and its theoretical base are important for parents and teachers of toddlers and preschoolers. The findings indicate that very young children are active problem solvers and use many different strategies during problem solving.
The findings also indicate that by age three verbal hints can be an effective way to help children in problem solving situations, but for children younger than two years old modeling is more effective. Parents and teachers can support cognitive development of young children by encouraging them to solve developmentally appropriate problems independently and if needed, provide just the right amount and kind of scaffolding at the right time to enable them to advance beyond their current skill level.
REFERENCES


APPENDIX

CODING FORMS
## Coding Forms

**14-inch Tube Problem Coding Form**

<table>
<thead>
<tr>
<th>Age group:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Younger (18-22 months old): 1</td>
<td></td>
</tr>
<tr>
<td>Older (27-36 months old): 2</td>
<td></td>
</tr>
<tr>
<td>Age (months)</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>ID #</td>
<td></td>
</tr>
</tbody>
</table>

**14-inch Tube Problem**

<table>
<thead>
<tr>
<th>Verbal help</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Modeling /assisting</td>
<td></td>
</tr>
<tr>
<td>Success with help</td>
<td></td>
</tr>
<tr>
<td>Success without help</td>
<td></td>
</tr>
<tr>
<td>Success</td>
<td></td>
</tr>
<tr>
<td>Unsuccessful strategies used: finger</td>
<td></td>
</tr>
<tr>
<td>Unsuccessful strategies used: tool</td>
<td></td>
</tr>
<tr>
<td>Unsuccessful strategies used: social</td>
<td></td>
</tr>
</tbody>
</table>

**14-inch Tube Problem**

| Number of different unsuccessful strategies used by the child |  |

**Inverted T-tube Problem Coding Form**

| Age group: |  |
| Younger (18-22 months old): 1 | Older (27-36 months old): 2 |
| Age (months) | | |
| Gender | | |
| ID # | | |

**Inverted T-tube Problem**

| Verbal help | Response scores |
| Modeling /assisting | 1-yes |
| Success with help | 0-no |
| Success without help | |
| Success | |
| Unsuccessful strategies used: finger | |
| Unsuccessful strategies used: tool | |
| Unsuccessful strategies used: social | |

**Inverted T-tube Problem**

| Number of different unsuccessful strategies used by the child | Response score |