1996

Strategic Transfer in Logical Abilities in Children Playing Mastermind and an Analogue

Cynthia J. Kincaid

Eastern Illinois University

This research is a product of the graduate program in School Psychology at Eastern Illinois University. Find out more about the program.

THESIS REPRODUCTION CERTIFICATE

TO: Graduate Degree Candidates (who have written formal theses)

SUBJECT: Permission to Reproduce Theses

The University Library is receiving a number of requests from other institutions asking permission to reproduce dissertations for inclusion in their library holdings. Although no copyright laws are involved, we feel that professional courtesy demands that permission be obtained from the author before we allow theses to be copied.

PLEASE SIGN ONE OF THE FOLLOWING STATEMENTS:

Booth Library of Eastern Illinois University has my permission to lend my thesis to a reputable college or university for the purpose of copying it for inclusion in that institution's library or research holdings.

_____   _____
               Author   Date

I respectfully request Booth Library of Eastern Illinois University <u>not</u> allow my thesis to be reproduced because:

_____

_____

_____

_____   _____
               Author   Date

Strategic Transfer in Logical Abilities in

Children Playing Mastermind and an Analogue
(TITLE)

BY

Cynthia J. Kincaid

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

Specialist in School Psychology

IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
CHARLESTON, ILLINOIS

1996
YEAR

I HEREBY RECOMMEND THIS THESIS BE ACCEPTED AS FULFILLING
THIS PART OF THE GRADUATE DEGREE CITED ABOVE

8/2/96
DATE

ADVISER

8/2/96
DATE

DEPARTMENT HEAD

Abstract

Strategy development and the use of strategy as a mechanism of transfer was examined in sixty elementary students while playing the logical deduction game Mastermind and a familiar analogue. In the first couple of two-way ANOVAs subjects showed that they are in fact learning or developing a task-specific strategy that can be applied across the two types of games regardless of which game was in the target position of a transfer paradigm. This suggests that subjects were able to focus on structural similarities rather than surface features and apply what was learned between the game isomorphs. Both the third and fourth ANOVAs indicate that strategic transfer did occur between the Family Dinner Table game and Mastermind game, when mastermind was in the target position of a transfer paradigm. This suggests that strategies can be used as a mechanism in transfer.

Acknowledgments

I would like to thank the faculty at Eastern Illinois University, in particular, my thesis committee Dr. John Best, committee chairman, Dr. Linda Leal, and Dr. Christine McCormick. I would also like to thank the Charleston Public School District administration, staff, and parents for allowing me to conduct my research with students attending Jefferson Elementary sixth grade classes in the Spring of 1995. I would especially like to thank my parents, Herbert and Pat Kincaid, for all their love and support throughout the years.

Table of Contents

List of Tables

CHAPTER I

Statement of the Problem

Many facets of human reasoning and problem solving have been examined by psychologists over the years. However, developing a clear understanding of the issues involved, and agreeing on a theoretical perspective in these areas has been difficult. A particular area that has been extensively investigated is how transfer of the mechanism used to solve a problem can be examined through the use of analogies. This issue can be viewed in several ways: as a task that requires finding and mapping higher-level analogies, a task of noticing problem similarity and abstracting a schema, a task of mapping productions from source to target problem, a task that depends on surface features, a task influenced by problem difficulty, a task sensitive to training on the source problem, a task dependent on problem familiarity, and a task that is dependent on move operator compatibility. All of these things have been proposed as the mechanism being used in analogy studies. Strategies as a possible mechanism, however, is an area in need of further examination. The use of strategies and the ability to transfer strategies to other structurally similar problems is not well understood. Children's reasoning abilities in these areas in particular need further investigation.

Purpose of the study

After examining research in this area, it became clear that a study identifying and examining the role of strategies as a mechanism of transfer in superficially different, but structurally similar problems would help researchers achieve a greater understanding of human problem solving. The use of children as subjects will create insight in the developmental aspect of human problem solving because few studies have used children as subjects

when examining reasoning and problem solving from an information processing or cognitive prospective.

Theoretical Background and Definition of Terms

A strategy is defined as an intentional plan that specifies an action to be taken. It is a common view that the outcome from the strategy circles back to the knowledge structure and changes the amount or the organization of knowledge, thus this changed knowledge structure contains a more superior strategy (Best 1990). A good strategy according to Newell and Simon (1972) is accessed in the knowledge structure, applied to the problem, and then the results of its application are incorporated back into the original knowledge structure. The knowledge structure will than contain a more superior strategy for the next problem. A schema can be defined as a general purpose or plan. A schema is comparable to a basic blueprint or outline that is general enough to be used in similar situations or problems, but specific enough so that it can not be used in all situations. For example, trial and error is too general; it can be used to solve all problems, while covering liquid to make it boil is too specific to be a schema. Consequently, a schema is at a medium level of abstraction. An example of a schema at the medium level of abstraction is that smaller objects can fit into larger objects. This problem solving schema can be used to solve a variety, but not all problems.

Historical Background on Transfer:

Transfer has been defined in many ways. A broad definition of transfer examines how prior experience affects later learning, or application of the known to the novel. According to Hulse, Deese, and Egeth (1975), transfer can be either general or specific. General transfer can be split into two categories: warm up and learning how to learn. Warm up is establishing a memory rhythm or finding an attending posture conducive to learning.

Learning to learn is the acquisition of learning skills with practice. For example, if a subject is asked to memorize lists of words he/she would become better at the task of memorizing the word lists by developing skills that improve his/her ability to memorize the word lists. The learning to learn category may include the use/development of a schema or strategy. Specific transfer occurs when specifiable similarities can be drawn between the stimuli and the response. An example of specific transfer is knowledge of math that can be transferred to physics. In addition to the various levels of transfer, it also can have varying effects on what is to be learned or what was previously learned. In other words, does transfer work equally as well in both directions?

A proaction and retroaction design helps to examine the effects of transfer. A proactive design contains both an experimental and a control group. The experimental group learns task A then learns task B and finally is given a retention test on task B. The control group rests instead of learning task A then learns task B, and is also given the retention test on B. If the experimental group does better on the retention test as opposed to the control group, positive transfer or proactive facilitation has occurred. This means that task A has helped facilitate the learning of task B. If the experimental group does worse than the control, negative transfer or proactive interference has occurred because task A has inhibited the learning of task B. If both groups perform equally on the retention test, no transfer has occurred. The retroactive design also contains both an experimental and control group. The experimental group again learns task A then task B, but is given a retention test for A. The control group learns task A then rests, and is given the retention test for A. If the control group performs better on the retention test than the experimental group, retroactive interference or negative transfer has

occurred. This negative transfer has undermined what was previously learned. If the experimental group performs better than the control, retroactive facilitation has occurred. Again, if both groups perform the same on the retention task, no transfer has occurred. This brief overview of transfer illustrates its complexity. Transfer can be general, specific, positive, negative, and effect previous or future knowledge.

Cognitive Psychology: Problem solving as search

Kotovsky and Fallside (1989) examined the role and effect of move operators on transfer. Briefly, move operators are a part of Newell and Simon's theoretical model of describing human problem solving. This model consists of a problem space that contains separate problem states. The move operators are the means from which you move from one problem state to the next until you reach the goal state. A strategy puts together smaller cognitive units, operators, in a sequential order. This is called temporal integration (Brown, Kane, and Echols 1986). Kotovsky and Fallside (1989) used isomorphic (structurally similar) problems to examine the role of move operators in determining the difficulty of the problem and transfer. It was discovered that the more difficult an isomorph was depended on the move operators. Thus the difficulty of establishing a strategy is determined by the move operators as well. The more difficult problems used move operators that imposed a greater processing load. Move operator difficulty was determined by the number of entities that had to be imagined to test the legality of a move. A legal move simply takes the problem solver from the current problem state to the next. Transfer occurred between problems that had compatible move operators. Move operator compatibility means that what an individual does to produce a change in a particular pattern in one array is alike or compatible to what an individual does to produce a change in

a different pattern array. Move operator compatibility seems to help facilitate transfer between two isomorphs (Kotovsky and Fallside 1989).

Kotovsky and Fallside (1989) also discovered that the problem solving process is twofold, and includes an initial phase and final path. The initial phase includes a problem exploration period during which people become expert enough at making moves to be able to plan. In the final path, people rapidly achieve a solution because they can plan move sequences that are within processing limitations. Which of these two phases is likely to be facilitated by the prior solution of an analogue? It was predicted by the experimenters that the exploratory phase of the problem solving process would be shortened by the skill learned in solving the source problem. This was what was discovered when the exploratory and final path move latencies were examined. When transfer occurs between two problems, it reduces the exploratory phase of the problem solving process, while leaving the final path phase of the process basically unchanged. In simple terms, what is transferred is the strategy or move pattern to the solution. This reduces the exploratory phase since this move pattern does not have to be developed, but does not change the final phase of the problem because the number of steps an individual can maintain cognitively to see the goal state remains the same. It appears that the target of transfer is learning to make moves. This learning then can be substituted for some of the learning that normally occurs during the exploratory phase. Once on the final path to solution, time remains the same regardless of rather subjects were given an initial problem to solve, if transfer occurred or did not occur, and regardless of level of representation. If the move pattern is not known, meaning a strategy is not developed, the exploratory phase will not be reduced making overall problem solution cumbersome and difficult to achieve.

Analogy: Factors that effect transfer

Many studies have been done on analogical transfer. All of these studies suggest that the level at which subjects represent problems plays a role in their success at solving the problem. In short, the studies have indicated that subjects are more likely to use a previous solution, transfer, if the analogues are similar in surface characteristics than if the analogues are structurally similar (Gentner, 1983; Gick & Holyoak, 1987; Holyoak & Koh, 1987; Kotovsky & Fallside, 1989). Surface similarities refers to superficial similarity. These similarities are based on appearances or classifications. Examples of superficial similarities include: color, size, and shape. Structural similarities refer to having the same purpose or causal features. A subject's ability to attend to structural similarities improves his/her performance. Relying only on surface similarities, inhibits performance because surface similarities are unrelated to the solution. However, superficial similarities are helpful because they are important in retrieval and mapping of similar problems. Problems containing both superficial and structural similarities are most likely to produce successful transfer. The superficial similarities will help retrieval and the structural similarities will allow successful solving of the target problem. Structure determines the strategy needed to solve the problem. Likewise the strategy must be understood at the appropriate level of abstraction for transfer to occur. Problems that share strategies or move operators in a sequential order are structurally similar, and will facilitate successful transfer if recognized. Research has shown that novices and children tend to rely on surface characteristics while experts rely on structural representations when solving problems (Kotovsky and Fallside, 1989).

Another factor that has been shown to affect a person's ability to solve a problem is his/her familiarity with the problem. This notion dates back to what is now known as the Wason selection task (Wason 1966). Wason presented adult subjects with four cards showing the symbols E,K,4,7. Subjects were told that each card had a number on one side and a letter on the other side. They were to turn over the fewest number of cards to confirm the rule: If a card has a vowel on one side, then it has an even number on the other side. The correct response is to turn over the E and 7, but 46 percent of the subjects turned over the E and the 4. This type of reasoning error is termed affirming the consequent. Johnson-Laird, Ligrenzi, and Ligrenzi (1972) demonstrated that the affirming the consequent reasoning error can be eliminated if the context in which the inference is demanded is known to the subject. In their study, subjects were shown four envelopes. Two envelopes had the address side facing up with the only difference between them being the postage, 40-lire and 50-lire. The other two envelopes had the address side facing down the only difference between theses envelopes was that one envelope was sealed while the other was not sealed. Subjects pretended that they were postal workers sorting letters. They were asked to turn over the minimum number of envelopes necessary to confirm the following postal rule: "If a letter is sealed, then it has a 50-lire stamp on it." In this study, 88 percent of the subjects correctly turned over the envelope with the 40-lire stamp on it and the sealed envelope. These two studies illustrate how two analogous problems can produce different reasoning abilities among subjects simply by changing the context of the problem from abstract to familiar. Later research by Griggs and Cox (1982) showed that context only enhanced performance if it used retrieval of directly experienced knowledge stored in permanent memory. These studies suggest that a

problem that can be related to a subject's experience should enhance performance.

Mastermind, and strategy use in Mastermind

The logical deduction game Mastermind consists of different colored buttons, white or black feedback pegs, and a peg board. The object of the game is for the child to deduce the left to right order of a string of buttons or the code in as few hypotheses as possible. The code is determined by the examiner, and consists of four different colored buttons. During the game, the code is hidden behind a shield on the peg board. To deduce the code, the child begins the game by taking colored buttons from the box, and placing them in the first row of the peg board. This represents the child's first hypothesis in figuring out the code. Two types of feedback are given to help the child determine the accuracy of his/her hypothesis. Black feedback means that there is a correspondence both in color and in location between a button in the child's hypothesis and a button in the code. White feedback means that a button in the hypotheses corresponds to a button in the code in color, but not in location. Feedback is given with little white and black pegs to the left of each hypothesis. The position of the feedback pegs does not correspond to the position of the buttons in the hypothesis. In other words the relationship between a given feedback and a button must be deduced. The child uses this feedback to make his/her next hypothesis. The child is given 9 chances to determine the code before the game is terminated.

Strategic transfer in Mastermind can be measured in two ways: the number of hypotheses advanced, and the use of modal hypothesis. Number of hypotheses advanced simply refers to how many hypothesis's the subject plays before solving the game. Subjects are told that the object of the game is not only to solve the code, but to solve the code in as few hypotheses as

they can. Consequently, the fewer hypotheses advanced would indicate that a subject has a good understanding of the problem space and a well developed strategy. In the Mastermind game, subjects usually change previous hypothesis to make their next hypothesis in a somewhat typical manner. For example, a subject may change two of the colors in a given hypothesis, selecting the two remaining colors from the pool that had not been used on the just previous hypothesis while leaving two colors played in the preceding hypothesis in the same location. Such a hypothesis, using the coding system developed by Best (1990) would be classified as a "two color" or a "2C" hypothesis. Subjects may also decide to change the location of previous used colors on a given hypothesis. For example, a subject may produce a hypothesis by reversing the order of two of the colors used in the previous hypothesis and leaving two colors alone. This hypothesis would be classified as a "two location" or "2L" hypothesis. In addition, a subject might make some combination of color and location changes in the same hypothesis. Previous research by Best (1990) indicates that college subjects usually produce a particular hypothesis type in response to each of the 13 feedback types possible. This predominant hypothesis response is termed a modal hypothesis. Since each feedback type possible has a corresponding modal hypothesis, there are 13 different modal hypotheses. For example, given a typical hypothesis and its associated feedback shown below:

Code:	red	green	black	white
Hypothesis:	red	yellow	white	blue
Feedback:	1 black, 1 white			

Based on the feedback the subject knows that one of the four colors played was played in its correct location in the sequence, and an additional color

played corresponds to a color in the code, but has not been played in its correct location in the sequence. The next hypothesis played to be classified as a modal hypothesis would need to utilize all the information given by the feedback by leaving one peg exactly the same both in color and location, keeping one color the same, but change its location, and changing two colors or a 2C 1L hypotheses. A modal hypotheses is important in strategy development because a modal hypothesis must be played in order to solve the code and win the game. The greater number of modal hypothesis played would be indicative of a subject having a well developed strategy and understanding of the problem space.

Review of Related Research

Holyoak (1984) stated that there is a four step process to analogical problem solving. First, the subject must construct a mental representation of the source and the target. Second, the source must be selected as a potential relevant analogue to the target. Third the components of the source and target must be mapped. Finally, this mapping process must be extended to generate a solution to the target. The second step is probably the most difficult of all the steps. Gentner (1983) proposed that information transferred from a source to a target analogue is constrained by a syntactic ordering. This is Gentner's terminology for discussing superficial and structural similarities effect on transfer. Syntactic ordering is quite logical in nature. Superficial features, one place predicates, are not transferred, while structural similarities, two place predicates/higher order predicates are transferred. Two place predicates/higher order predicates, refer to the relationships or causal features between source and target analogue. It is also important to note, that these steps in analogical problem solving do not have to occur in serial order; they can occur simultaneously or in varying orders.

Gick and Holyoak (1983) describe the process of problem solving by analogy through schema induction.

An alternative account involves eliminating the differences between the analogues while maintaining their commonalties. A schema would then be an abstract category that a given analogue would draw upon to solve the problem. Many such studies on analogical transfer suggest that subjects are more likely to use a previous solution if the analogues are similar in surface characteristics than they are to transfer when the analogues are structurally similar. Holyoak and Koh (1987) examined surface and structure similarity in analogical transfer. Their study contained four story analogues to the target radiation problem. The radiation problem is that a patient has a tumor that needs to be destroyed by radiation, but in order to get the radiation intensity high enough to destroy the tumor, healthy tissue will be destroyed. The solution to the problem is to administer low-intensity rays from multiple directions simultaneously (convergence solution). The four story analogues were variations of the light bulb problem. The light bulb problem is that an expensive light bulb in a physics lab is broken. The light bulb was completely intact, and an intense laser could be used to fuse the filament. This high intensity laser, however, would brake the glass surrounding the filament. A low intensity laser would not break the glass, but it would also not affect the filament. The solution is to direct multiple low intensity lasers toward the filament from different directions (convergence solution). The other three story analogues were generated by varying surface and or structure similarities to the original light bulb problem. All subjects were given one version of the light bulb problem and then were asked to summarize it. Subjects were then given the radiation problem and asked to write as many solutions as they could think of. Finally, subjects were given a

questionnaire that asked whether or not they tried to use the light bulb problem, what solution to the problem was suggested by the story, and whether they knew the problem and its solution prior to the experiment. The results indicated that when the light bulb story was both surface and structurally similar to the radiation problem, 69% of the subjects spontaneously generated the convergence solution. Transfer was significantly hindered if either surface similarity or structural similarity was reduced. Structural dissimilarity significantly impaired total transfer. In short the results suggest that surface similarity will have greater impact on retrieval of a source analogue than on its application, but structural similarity equally impacts both retrieval and application.

Another view point is presented by Brown, Kane, and Echols (1986) in a study that examined analogical transfer in 3- to 5-year old children. Three analogue problems were used: the genie, the rabbit, and the farmer. There were three experimental conditions to control level of abstraction. The first was the explicit goal structure. In this condition the children were asked a series of questions after each analogue story: who has a problem (protagonist); what did the protagonist want to do (goal); what is stopping the protagonist (obstacle), and finally the solution was requested. In the recall condition children were simply asked to tell all they could remember about the first analogue story. After completing the second analogue story, the children in this condition were asked the series of questions from the explicit goal structure condition. The three problems were administered without interruption in the control condition. Significant differences were obtained between conditions. The explicit goal structure group out-performed the recall group and the recall group out-performed the control group. Also, the older children, 5-year olds, transferred more in all conditions. This study

showed that children are capable of analogical transfer, and it suggests that the level of abstraction effects how well a subject will transfer. This study did not, however, examine strategy development or strategy transfer.

Transfer is a complex issue within the human problem solving literature. By this brief overview it is easy to see that there are varying theories as to how to facilitate transfer, why transfer occurs, at what level of representation does transfer occur, and what direction does transfer occur. Transfer is typically examined through analogies or isomorphism and the research illustrates that the representation similarity between these is directly related to the amount of transfer obtained. The greater the representational overlap, whether it be at the surface level, structural level, or operator level, the more likely transfer will be increased. It is important to remember that successful transfer relies on individuals' ability to use structural or internal features of the problem rather than surface features in guiding their use of previous problem schema to a novel problem.

Hypotheses

Children were used as subjects to examine if their reasoning abilities are similar to those of adult subjects. The previous literature suggests that, on the basis of their experience in the domain, subjects will build a task-specific strategy for both the Mastermind and Family Dinner Table (a developed analogue) tasks. It is hypothesized that this strategy will be associated with an improvement in performance across the two games that subjects play, and will be seen as main effects in ANOVAs. The ANOVAs will examine subject performance in terms of hypotheses advanced (which should significantly decline in the second game, regardless of task), and proportion of modal hypotheses produced (which should significantly increase in the subject's second game, regardless of task).

Second, based on the isomorphic relationship between the two tasks, it is expected that subjects will exploit those structural similarities as an aid in transferring strategic knowledge acquired on one task to the other. Specifically, the expectation is that Family Dinner Table will produce greater transfer onto Mastermind in the target position than Mastermind will produce onto itself in the target position. In other words, the expectation is that ANOVAs focusing on both the number of hypotheses advanced, and proportion of modal hypotheses produced will indicate a significant interaction between the variables task sequence (two levels: FDT-MM, and MM-MM) and task number (two levels: first task attempted, second task attempted).

CHAPTER II

Method

Design

A between subjects experimental design was used. Students were randomly assigned to one of three conditions in the study. In one condition, subjects played two consecutive games of Mastermind (MM-MM). In the second condition, subjects played the Mastermind game first and than the Family Dinner Table game (MM-FDT). The third condition was similar to the second, except subjects played the two different games in reverse order (FDT-MM). This design allowed for several comparisons to be made in order to examine strategy development and strategic transfer. In order to examine whether or not subjects were able to build a task-specific strategy while playing the two different games across their episodes of playing the MM-FDT and FDT-MM experimental groups were compared. The second comparison made looked at transfer effects. In order to examine transfer the MM-MM and FDT-MM experimental groups were compared.

Subjects

Sixty sixth grade students attending Jefferson Elementary School in Charleston, Illinois volunteered to participate in the study by obtaining written permission from their parents. Jefferson Elementary School houses all the sixth graders in the community. Charleston is a rural community with a variety of social economic status and little ethnic diversity. Each experimental group contained ten male subjects, and ten female subjects.

Materials

A personally developed analogue called the Family Dinner Table game (FDT), and the Mastermind game were used. The FDT analogue consists of pictures of family members on colored Velcro discs, white and black

feedback in the form of pineapples and ice-cream cones on Velcro discs, a
Velcro game board with nine identical pictures of a family dinner table and a
Velcro code board with one family dinner table on it. The pictures of the
family member on the colored Velcro discs were simply facial representations
of characters in a children's story book. Half of the family member pictures
were male and half were female. Family member pictures were ambiguous
in terms of age and ethnicity. The problem is that there are six members in
this family, but only four are home for dinner.   Everyone in this family sits
at a special place while eating. The object of the game is for the child to
deduce who is home for dinner and were they sit (the code) in as few
hypotheses as possible. The FDT game is an isomorph to the Mastermind
game in which the object of the game is for the child to deduce the left to
right order of a string of colored buttons (the code) in as few hypotheses as
possible. In other words, the six different family member discs in FDT are
equivalent to the six different colored pegs in Mastermind, and the four seats
at the dinner table in FDT are equivalent to the four different row positions in
Mastermind. The code is determined by the examiner, and hidden in both
FDT and Mastermind games. The code is placed on the Velcro code board
and hidden behind a table cloth in FDT, while the code is hidden behind a
shield on the game board in Mastermind. The child begins the FDT game by
choosing four of the possible six family member discs and placing them on
the chairs on the first table, and begins the mastermind game by choosing
four of the possible six colored pegs and placing them in a position on the
first row.   This represents the child's first hypothesis in figuring out the code
in both games.   The child will receive two kinds of feedback based on
his/her hypothesis to assist in figuring out the code. A pineapple (white
feedback peg in mastermind) is given if the child has the correct family

member at home eating, but they are in the wrong seat (correct colored peg in the wrong row position in mastermind). An ice-cream cone (black feedback peg in Mastermind) is given if the correct person is home and in the right seat (correct colored peg and correct row position in Mastermind). Feedback symbols in FDT were chosen to represent desserts of varying quality. Ice-cream cones are considered a better dessert than pineapples in the eyes of most children and black feedback is considered better than white feed back by most subjects. Consequently, the feedback symbols themselves corresponded with the perceived quality of information they provided. The feedback does not correspond in a one to one relationship, meaning the child has to use logical deduction to determined which seat/person or colored peg/position pair earned the feedback. The subject uses the feedback to make their next hypothesis. All subjects were given 9 chances to determine the code before a game was terminated.

Procedures

    The experimenter administered the games to only one child at a time. Subjects were given 15 minutes to play each game. Prior to the study, subjects were simply informed that they will be playing two consecutive games. The experimenter recorded the subjects hypotheses and feedback on a separate sheet, after each hypothesis was played. Subjects were given instructions prior to playing their first game of Mastermind and Family Dinner Table. In order for the Family Dinner Table game instructions to be given to the subjects, the family member game pieces needed to be named. Because children live in various home life situations (traditional or non-traditional), it was possible that a bias might occur if the examiner arbitrarily named the family members. For example, if traditional family roles were used, such as, mom, dad, brother, and sister a child living in a non-traditional

home may be at a disadvantage because the game is less like their own life experience and thus more cognitively taxing. In order to eliminate such a bias from occurring, the subjects were allowed to name the six family members. The examiner helped facilitate this process. For example, the child was told there are six members in this family, while holding up one family member the examiner said, "This is a boy member of the family who should it be?" If the child does not respond, the examiner prompted the child by saying, "How about dad, step-dad, brother, uncle, or grandpa." This procedure was done until all family members had been named. The examiner then used these family names for the remainder of the game instructions and trials. This procedure was done to help keep the analogue as similar to the individual child's experience as possible.

CHAPTER III

Results

Several different types of data were collected in order to examine and compare subjects performance: (1) The number of hypotheses advanced by each subject was recorded by counting the number of hypotheses each subject made in each game until it was solved, with fewer hypotheses indicating greater skill in deduction. Since subjects are only given nine opportunities to play a hypotheses prior to game termination, subjects who did not solve the game obtained a score of nine. (2) The proportion of games solved by the subjects were recorded by the hypothesis number advanced upon solution or by an asterisk beside hypothesis nine if the code was never solved. Of the sixty subjects participating in the study, eight were unable to solve the code in either game trial. (3) Subjects were asked to rate their familiarity with the mastermind game using a familiarity code. All sixty subjects indicated choice one on the familiarity code which states: I never heard of it before today, or I've heard of it, but never played it. (4) Modal hypotheses were categorized for each game attempted using the scheme developed by Best (1990). For each game attempted by each subject, the number of modal and non-modal hypotheses were recorded, and the proportion of modal hypotheses computed. (5) Hypothesis type chosen in response to various feedback types was recorded for all mastermind and family dinner table games played.

Table 1

Data Summary for Mean Number of Hypotheses Advanced

	MM - MM	MM - FDT	FDT - MM
First Game	5.95	6.3	7.2
Second Game	7.3	6.3	6.7

Table 2

Data Summary for Percentage of Modals

	MM - MM	MM - FDT	FDT - MM
First Game	.62	.46	.56
Second Game	.48	.60	.64

In order to determine if subjects were able to build a task-specific strategy while playing the game isomorphs across their two trials of playing, collapsed across the two different games played the experimental groups, MM-FDT and FDT-MM were examined. Two two-way analyses of variance were conducted, one with the dependent variable Percentage of Modal hypotheses used, and one with the dependent variable Hypotheses advanced. Both two-way ANOVA's contained a within subjects variable and a between subjects variable. The between subjects variable was order, and it had two levels, MM-FDT (order 1) and FDT-MM (order 2). The within subjects variable was game number, where "1" meant first game collapsed across game type and "2" meant second game collapsed across game type.

Using Percentage of Modal hypotheses as the dependent variable, the two-way ANOVA indicates that there was a main effect of game number. Subjects had a significantly higher percentage of modal hypotheses on their second games (M=.63) compared to their first games (M=.51), regardless of game type [$F(1,38) = 4.83$, p=.03, MSE =.054]. The second independent variable order and the interaction effect were not significant. Based on the ANOVA, the subjects made a higher percentage of modal hypotheses on their second game, regardless of whether the game was MM or FDT.

Using Hypotheses advanced as the dependent variable, where more hypotheses advanced equals poorer performance, the two-way ANOVA

results are similar to those found when examining percentage of Modal hypotheses. Subjects made fewer hypotheses while playing their second game ($\underline{M}$second game = 6.5) compared to their first game ($\underline{M}$first = 7.25), [$F(1, 38) = 3.58$, $\underline{p} = .07$, $\underline{MSE} = 3.14$]. These results approached significance at the .05 level. Again, the second independent variable order and the interaction effect were not significant.

In order to determine if strategic transfer occurred between the Family Dinner Table game and Mastermind game, when Mastermind was in the target position of a transfer paradigm the experimental groups MM-MM and FDT-MM were examined. Again, two ANOVA's were conducted, one with the dependent variable Percentage of Modal hypotheses used, and one with the dependent variable Hypotheses advanced.

The ANOVA results with Hypotheses advanced as the dependent variable indicate that subjects did get better when they played MM second after FDT first, but not when the played MM second after MM first [$F(1,38) = 3.44$, $\underline{p} = .07$, $\underline{MSE} = 4.96$]. Table 1 shows the mean number of hypotheses advanced.

Table 3

	Hypotheses Advanced	
	Variable A (first game, second game)	
	1	2
B1 MM MM	5.95	7.3
B2 FDT MM	7.2	6.7

The ANOVA results with Percentage of Modals as the dependent variable are consistent with the previous analysis [$F(1,38) = 4.3$, $\underline{p} = .04$, $\underline{MSE} = .063$]. The FDT-MM group had a higher percentage of modals

in their second game (when they did better in terms of number of hypotheses advanced) compared to their first game. The MM-MM group played a lower percentage of modals in their second game than in their first game, and did poor in terms of hypotheses advanced in their second game.

Table 4

	Percentage of Modals	
	Variable A (first game, second game)	
	1	2
B1 MM MM	.62	.48
B2 FDT MM	.56	.64

CHAPTER IV

Discussion

An ANOVA examining the experimental groups, MM-FDT and FDT-MM, in terms of percentage of modal hypotheses used supported the first hypothesis. The main effect was significant indicating that subjects had a higher percentage of modal hypotheses on their second game, regardless of whether the game was MM or FDT. This suggests that subjects are able to build a task-specific strategy based on their experience in the domain that can be applied across the two types of games played, regardless of which game was in the target position. Further support for this claim was obtained by examining the same two experimental groups in terms of hypotheses advanced. The main effect in this ANOVA approached significance indicating that subjects did in fact make fewer hypotheses while playing their second game compared to their first game. These combined findings suggest that subjects were able to focus on structural similarities rather than surface features and apply what was learned between the game isomorphs.

An ANOVA examining the experimental groups, FDT-MM and MM-MM, in terms of percentage of modal hypotheses used supported the second hypothesis. The interaction effect between game sequence and game number was significant indicating that subjects who played the Family Dinner Table game first rather than Mastermind were better able to apply the modal hypotheses strategy while playing Mastermind, their second game. This suggests that positive transfer did occur between the Family Dinner Table game and Mastermind game, when Mastermind was in the target position of a transfer paradigm. Further support for this assertion was obtained by examining the same two experimental groups in terms of hypothesis advanced. The interaction effect in this ANOVA was almost significant in

the direction predicted indicating that subjects made fewer hypotheses while playing Mastermind after they had played Family Dinner Table than after playing Mastermind itself. Together these findings suggest that strategies can be used as a mechanism in transfer.

Further investigation of the two ANOVA's examining the experimental groups MM-MM and FDT-MM indicate that the second hypotheses was only partially confirmed. The expectation was that Family Dinner Table would produce greater transfer onto Mastermind in the target position than Mastermind will produce onto itself in the target position. The former portion of this expectation was confirmed by the interaction effects as previously discussed. However, if the two ANOVA's are compared an interesting pattern of performance develops. The MM-MM group got $\underline{M}$ = 5.95 hypotheses advanced in their first MM game and a 62 percentage of modals. In comparison, the FDT-MM group played 64 percent modals in their first game of MM, which was their second game played, and got M = 6.7 hypotheses advanced. It would be expected that the hypotheses advanced in the FDT-MM group be comparable to the MM-MM group with approximately 6 hypothesis advanced. However, the FDT-MM group performed considerably worse than 6 hypotheses. This would suggest that playing FDT may have hurt the subjects performance slightly on MM in terms of trying to interpret feedback. This pattern of data suggests that perhaps it was easier to develop the modal strategy in MM after playing FDT, but it may have been harder to interpret the feedback in MM after playing FDT first.   The latter portion of the expectation did not occur as Mastermind did not produce positive transfer onto itself in the target position. In fact Mastermind had an adverse effect on itself with performance declining on the second game of the MM-MM group both in terms of hypotheses advanced

and percentage of modal hypotheses used. This complicates the data because it is expected that the second game played by the MM-MM group would increase or at least remain the same due to subjects formulating a task-specific strategy. Two possible reasons are offered to explain these findings. First, perhaps subjects got bored playing two games of the same thing in a row. Second, subjects may have tried to expand upon their already developed strategy by incorporating not only the just previous hypothesis, but several previous hypotheses. Such a task may have become too difficult for the subjects to maintain cognitively, creating frustration and a failure to use the already developed strategy.

The reviewed research indicates that subjects are more likely to establish a strategy between isomorphs when move operators are less complex and more compatible. Since ANOVA results indicate that subjects did build a task-specific strategy and applied it across the game isomorphs, researchers such as Kotovsky and Fallside (1989) and Brown, Kane, and Echols (1986) would conclude that the game isomorphs Mastermind and Family Dinner Table have simplistic and compatible move operators. Consequently, the results obtained would not be contradictory to previous research in the field. However, what was surprising is that subjects were able to focus on the structural similarities rather than the surface similarities (which were not available) and apply what was learned between the games. Studies by Gentner (1983), Gick & Holyoak (1987), and Kotovsky & Fallside (1989) indicate that subjects are more likely to use a previous solution, transfer, when isomorphs are similar in surface characteristics than when structurally similar. In particular, Kotovsky and Fallside (1989) state that novices and children tend to rely on surface characteristics while experts rely on structural similarities when solving problems. It appears that these findings regarding

surface and structurally similarities are contradictory to other research in the field.

Move operator compatibility as the potential mechanism involved in transfer proposed by Kotovsky and Fallside (1989) is closely related to the idea that a strategy is the mechanism involved in transfer. This is felt because a strategy can be defined as a putting together of smaller cognitive units, move operators, in a sequential order. Consequently, the less complex the move operators are the easier it would be develop a strategy. Strategies as a mechanism in transfer would decrease the processing load by chunking moves together and move the solver from the current problem state to the next more efficiently.

A limitation of the study emerged when game isomorphism was examined. The Family Dinner Table game structurally is isomorphic to the Mastermind game. However, two surface feature elements added to the complexity of the Family Dinner Table game because of the subjects life experience. One of these factors home life was controlled by having subjects name the family members themselves. However, even the process of naming the family members added a surface feature difference because subjects were not asked what should we call this color. The second life experience element that may of impacted subject performance was number of family members in their actual family. In other words, for a child who has six family members, but typically only four members are home for dinner at a time may have found this game less cognitively demanding because of their own life experience. While both of these factors could have effected subject performance, it did not appear to be based on the subject self talk during playing the FDT game. Subjects seemed to focus on the colored backgrounds of the family member discs when referring to a family member

game piece rather than using the family member name, and subjects did not make reference to the number of members in their own family while playing the game. In future studies, to further eliminate a subjects life experience from aiding or inhibiting performance subjects could simply be asked to play a game about a pretend family.

References

Best, J. (1990). Knowledge acquisition and strategic action in "Mastermind" problems. Memory & Cognition, 18, 54-64.

Brown, A. L., Kane, M.J. & Echols, C.H. (1986). Young Children's Mental Models Determine Analogical Transfer Across Problems with a Common Goal Structure. Cognitive Development, 1, 103-121.

Gentner, D. (1983). Structure-mapping: A Theoretical Framework for Analogy. Cognitive Science, 7, 155-170.

Gick, M.L. & Holyoak, K.J. (1987). Schema Induction and Analogical Transfer. Cognitive Psychology, 15, 1-38.

Griggs, R.A., & Cox, J. R. (1982). the elusive thematic-material effects in Wason's selection task. British Journal of Psychology, 73, 407- 420.

Holyoak, K. J. (1984). Analogical Thinking and Human Intelligence. In R.J. Sternberg (Ed.), Advance in the Psychology of Human Intelligence (Vol. 2) Hillsdale, NJ: Erlbaum.

Holyoak, K.J. & Koh K. Surface and Structural Similarity in Analogical Transfer. Memory and Cognition, 15, 332-340.

Hulse, S.H., Deese, J., Egeth, H. (1975) Interference theory. In the Psychology of learning (4th Ed.) New York: McGraw-Hill.

Johnson-Laird, P.N., Ligrenzi, P., & Ligrenzi, M. (1972). Reasoning and a sense of reality. British Journal of Psychology, 63, 395-400.

Kotovsky, K. & Fallside, D. (1989) Representation and Transfer in Problem Solving. In D Klahr and K. Kotovsky, (Eds.), Complex Information Processing: The Impact of Herbert A. Simon. (pp69-108). Hillsdale, NJ: Erlbaum.

Newell, A. & Simon, H.A. (1972) Human Problem Solving.
    Englewood Cliffs, NJ: Prentice Hall.

Wason, P.C. (1966) reasoning in B.M. Foss (Ed.) New horizons in
    Psychology, (Vol. 1) Harmondsworth, Middlesm England: Penquin.

Appendix

Instructions for Mastermind and Family Dinner Table

Mastermind Familiarity Code

Instructions for Mastermind

Hello, and thanks for being here today. We're going to play a game called Mastermind. It looks like this (show box). In this game, your job will be to figure out the hidden sequence of four colored buttons. We call this hidden sequence the "code". In the actual game, the colored buttons will be hidden behind this shield (show them). In order to figure out the hidden sequence, you take colored buttons from this side of the box and place them here (Place a code, and a hypothesis in the first row). Now in order help you figure out the hidden code I will give you feedback on how accurate you are.

Feedback comes in two types. One type of feedback (black feedback) means that there is a button in the code that matches yours in both color and in location. The other type of feedback (white feedback) means that there is a match in color but not location. So in this example:

Code   Gn Yw Bl Wh

Hyp   Gn Bk Rd Yw

you would get one black pin because there is a match in color and location for the Green button, and you would get one white pin because there is a match in color, but not location, for the yellow button. It doesn't matter which one of these four places that I put the feedback pins in. Your job is to figure out the code in as few tries as possible--not necessarily in as little time as possible. In fact you can take as long as you'd like between making each hypothesis, but we only have 15 minutes to play each game. One more thing that will be helpful for you to know -- no color will appear in the code more than once.

Instructions for Family Dinner Table:

Hello. and thanks for being here today. We're going to play a game called Family dinner table. It looks like this (show poster board). In this game, your job will be to figure out what family members are home for dinner and

where they sit. You see there are six members in this family and only four of them are home for dinner and they all sit in a special seat. I have the answer here and during the actual game it will be hidden under this table cloth. In order to figure out who is home for dinner and where they sit, you take a family member from this box and place them here (Place a code, and a hypothesis in the first table). Now in order help you figure out which family members are home for dinner and where they sit. I will give you feedback on how accurate you are.

Feedback comes in two types. One type of feedback (ice cream cones) means that you have the right family member home for dinner and they are sitting in the right chair. The other type of feedback (pineapples) means that you have a correct member of the family at home for dinner, but they are sitting in the wrong chair.

So in this example:

Code   Gn   Yw   Bl   Wh
Hyp   Gn   Bk   Rd   Yw

you would get one ice cream cone because there is a match in family member and seat (the experimenter points to the person token with the green background), and you would get one pineapple because there is a person who is home for dinner, but isn't sitting in the right seat (the experimenter points to the person token with the yellow background). It doesn't matter which one of these four places that I put the feedback in. Your job is to figure out who is home for dinner and where they sit in as few tries as possible--not necessarily in as little time as possible. In fact you can take as long as you'd like between making each try, but we only have 15 minutes to play each game.

Mastermind Familiarity Code

1. I never heard of it before today, or I've heard of it, but never played it.

2. I've played it before once or twice.

3. I've played Mastermind several times before.

4. I've played Mastermind dozens of times.

5. I play Mastermind at least once per week, and I've done so for at least a year.