AN ANALYSIS OF INCUBATION EFFECTS IN PROBLEM SOLVING USING A COMPUTER-ADMINISTERED ASSESSMENT TOOL

A Dissertation

by

SUNG AE YOO

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 2008

Major Subject: Educational Psychology

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Approved by:

Chair of Committee,	Ronald Zellner
Committee Members,	William Nash
	Steven Smith
	Victor Willson
Head of Department,	Michael Benz

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ABSTRACT

An Analysis of Incubation Effects in Problem Solving Using a Computer-Administered Assessment Tool. (May 2008)

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M.Ed., Texas A&M University

Chair of Advisory Committee: Dr. Ronald Zellner

An insightful solution to a problem may be promoted by temporarily being away from the problem at hand and engaging in other tasks or problems. Wallas (1926) conceptualized such an interruption period between problem solving activities as an incubation period. The present study examines the effect of such activities that are provided as an incubation period in computer-based problem solving tasks. In addition, this study explores the potential interaction between the type of problems and the type of interruption tasks involving two types of problems (verbal and spatial) and two types of interruption activities (verbal and spatial).

One hundred eighty five undergraduate volunteers participated. The participants were randomly assigned to one of the six conditions, Spatial Problems: No-Interruption Task, Spatial Problems: Verbal Interruption Task, Spatial Problems: Spatial Interruption Task, Verbal Problems (Anagrams): No-Interruption Task, Verbal Problems (Anagrams): Verbal Interruption Task, and Verbal Problems (Anagrams): Spatial Interruption Task. A computerized technique was developed and incorporated for data collection and material presentation. This technique was considered to have advantages over the conventional data collection format because of its ability to (1) standardize the presentation and assessment of problem solving tasks, (2) allow subjects to manipulate the problem components as they desire, simulating real world problem solving approaches, and (3) monitor the subjects' on-going interactions through the use of intricate, covert, data collection techniques. Regression analyses were employed to analyze the data collected using this computerized technique.

The findings from the present study partially support the view that problem solvers can benefit from a temporary interruption task in a problem solving sequence. The participants resolved the problems more quickly when distracted by an intervening simple cognitive task than when allowed to work continuously. It was implied that a problem solver could benefit from an interruption that involves stimuli changing visually and spatially and that also demands some degree of cognitive involvement. Although the present study did not demonstrate effects of interaction between the problem types and interruption types, the findings suggested that in the case of spatial problems, engaging in an incubation activity is likely to result in more efficient performance.

DEDICATION

I dedicate this dissertation to:

My husband, Woodong Jung
My son, Heejae Jung ("Tony")

and
my father, Bum-Ho Yoo and my mother, Ju-Wha Kim
for their love and support.
my father-in-law, Moon-Dal Jung
for his love and support.
and
all of my family for their love and support.

and
all who love me.

Thank you.

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr. Zellner, and my committee members, Dr. Nash, Dr. Smith, and Dr. Willson, for their guidance and support throughout the course of this research.

Thanks also go to my friends and colleagues and the department faculty and staff for making my time at Texas A&M University a great experience. I also want to extend my gratitude to all the Texas A&M students who were willing to participate in the study.

Finally, thanks to my parents for their encouragement and to my husband and son for their patience and love.

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CHAPTER I

INTRODUCTION

When confronted with an initial failure while working to solve a problem, an individual may repeat the ineffective problem solving approach over and over in vain. In this situation, the problem solver may feel frustrated and see no alternative way to approach the solution. The problem solver may continue to work on the problem or may decide to stop and return to it sometime later. The present study examines how problem solvers may benefit from temporarily being away from the unsolvable problem at hand by focusing on another task, and then returning to the problem later. The question is: does the intervening activity affect the final resolution of the problem?

Role of Incubation

The present study focused on problems where their solutions are considered to involve the restructuring of thinking or the developing of an insight, i.e., insight problems. Bowden (1997) argued that insight problems are distinguished from other problems by three properties: (1) When working an insight problem, the problem solver often experiences an impasse due to the initial misinterpretation of the problem or unwarranted assumption for the solution to the problem, (2) the problem solver experiences a solution with suddenness and surprise, and (3) the problem solver has difficulty describing his/her processing that leads to solution.

This dissertation follows the style of *Journal of Creative Behavior*.

In solving such problems that require insight or creativity, incubation is generally considered to enhance the problem solving process. Initially, Wallas (1926) conceptualized that creative cognition in problem solving was considered to involve four process stages: preparation, incubation, illumination, and verification. In the preparation stage, the problem solver applies skills or knowledge to a novel problem. The problem solver may be successful in applying his known skills or knowledge to the problem in his/her initial attempt. However, when confronted by the initial failure on a problem, the problem solver intentionally or unintentionally diverts his/her attention from the problem at hand by focusing on something else; this is considered the incubation stage. While the problem solver is focused on this other task, a moment of illumination is often encountered. Illumination refers to the experience that an insight flashes into consciousness resulting in a return to the problem solving task. Finally, this new insight is judged in its effectiveness in the subsequent verification stage.

More recently, incubation has been researched in terms of cognitive processing and mental structure (e.g., Smith and Blankenship, 1989, 1991; Smith, Ward, & Finke, 1995); Weisberg & Alba, 1981; Yaniv & Meyer, 1987). Incubation is considered to be the result of relevant solution knowledge retrieval after diverting attention from the problem at hand. Basically, expanding the ideas of incubation from the original Wallas (1926) and Woodworth and Schlosberg (1954)'s four stages of problem solving process, Finke, Ward, and Smith (1992) defined incubation as the following:

> Incubation refers to cases in which a problem is set aside temporarily after an initial impasse is reached. The problem can then be solved more easily when attention is returned to it, or a solution may suddenly burst into the problem solver's awareness even without intentionally returning to the problem (p.149).

Similarly, Weisberg & Alba (1981) conceptualized incubation to be not a period of total removal from the problem task but one in which some sort of solving activity continues; where activation of memory can then provide the basis for generating creative strategies for solving the problem. In their view, problem solvers benefit from an incubation period because they actually continue to work covertly on the problem during that period.

In support of an alternate interpretation of the incubation effect, Smith (1995a, 1995b) suggested that the interruption of work on the problem may be beneficial because a mental block, or fixation, is overcome as a result of the delay. This removal of the mental impasse was interpreted to increase the ability to recall the memory that is crucial for resolving the problem at hand. Put another way, having a break or doing something else helps the problem solver forget the prior ineffective approach that he/she applied to the problem and then seek a different, more successful solution strategy upon returning to the problem.

A Computerized Technique

The development of a research methodology that might standardize the assessment process for problem solving tasks can provide more definitive evaluation of the effects of intervening activities. To accomplish such a goal, this current study incorporated an interactive, computerized presentation format. In this format the computer governed all the administration procedures such as assigning subjects to an experimental condition, guiding subjects through the experiment process, providing problems and interactive materials, monitoring of the subjects' interactions through the use of intricate, covert, data collection techniques, and converting the monitored interactions to data files. Conventional paper-pencil assessment formats can provide information only about subjects' final outcome or level of accuracy. They do not provide information about the subjects' sequential interaction with the problems over time. Therefore, the conventional methods have a limitation in providing any information about the processes underlying the subjects' on-going interaction with the problems. In comparison, the computerized method used by the current study makes it possible to unobtrusively track and record participants' interaction with the problems. This tracking ability also allows revealing potential behavioral patterns associated with cognitive phenomena such as fixation and insight that are otherwise hard to examine. Chapter II of this document presents the computerized technique in depth.

Terminology

Based on the Finke, et al.'s (1992) definition of incubation, the present study defines the incubation phenomenon as: a solution process becomes more efficient when interrupted by an irrelevant task, rather than when the problem solving session is continuous. An incubation period is defined as the intervening time period when the problem solver stops working on the problem at hand and is temporarily engaged in a competing task that diverts his/her attention from the problem solving process. An interruption is the activity that a problem solver engages in during the incubation period. This study operatively defines incubation effects as improvement in problem solving performance of the participants who work on an interruption compared to those who continue working on the problems without being interrupted.

Research Questions

The primary goal of this study is to examine the role of incubation in the solving of insight problems. There has been moderate empirical research on the role of an incubation period (or task) in problem solving and findings from the studies do not seem to come to an agreement on the interpretation of the incubation phenomena. In the early incubation research, few experiments were able to support the effect of incubation (e.g., Patrick,1938; Silveira,1971). Many studies reported no effects or limited effects (e.g. Gall & Mendelsohn, 1967; Dominowski & Jenrick, 1972; Olton, 1979; Olton & Johnson, 1976). More recently, some researchers reported positive effects on problem solving ability due to incubation (Goldman, Wolters, & Winograd, 1992; Smith & Blankenship, 1989, 1991; Smith &Vela, 1991). To further examine the role of incubation in problem solving, this study compares the problem solving performance of participants who were interrupted by an intervening activity (the treatment groups) to the performance of those who continuously worked without being distracted (the control group).

The second goal of this study was to examine the potential interaction between insight problem types and interruption types. Research on incubation most often has included only one type of question and one type of interruption. Thus, a possible interaction between the type of questions and the type of interruptions could not be addressed. To examine this potential, this study included two types of problems and two types of interruption activities. The problems and tasks employed in the current research were divided based on the dominant problem solving processes that each requires.

Chapter III of this document provides details of the experiment procedures and study results regarding these two research goals.

Accordingly, the following research questions were posed:

1) Do the two interruption groups, combined and individually, perform differently on the final problem solving tasks from the no-interruption group (or continuous working group) on each type of insight problem?

2) Is there interaction between the two types of insight problems [verbal (anagrams) and spatial], and two types of interruptions (verbal and spatial)?

CHAPTER II

A COMPUTERIZED TECHNIQUE TO ASSESS EFFECTS OF INCUBATION ON PROBLEMS

Introduction

How can we measure incubation effects on problem solving? Conventional paper and pencil problem solving assessments provide researchers only the final outcome, i.e., only information about the correctness of responses. In contrast, a computerized assessment tool can enable researchers to record specific cognitive interactions throughout the entire problem solving sequence. The present study introduces such a computerized assessment technique designed to examine the incubation phenomenon in problem solving and its effects on problem solving performances. Specifically, the technique was used to measure performance patterns, accuracy, and efficiency.

Problem solving processes have long been an important topic of study in psychological research. Thorndike (1898) concluded that problem solving is a series of unintentional trial-and-error processes in which unsuccessful attempts are gradually reduced until a solution is eventually found. In contrast, John Dewey (1910) viewed problem solving as a purposeful and critical thinking process governed by a sequence of four steps: recognition of a problem, defining the problem, developing hypotheses, and testing the hypotheses. Köhler (1969) and other Gestalt Psychologists suggested that problem solving is a process which results in a sudden insightful awareness of the solution.

More recently, problem solving has been presented as involving a sequence of five stages (e.g., Anderson, 1993; Hayes, 1988; Newell & Simon, 1972): identifying the problem, representing the problem, searching possible solutions, evaluating the solutions, and applying the solutions. Accordingly, the problem solver initially forms a cognitive representation of the problem consisting of information that is active in working memory. Some visual representation such as a diagram on paper or on a computer-screen may also be utilized (Gagne, Yekovich, & Yekovich, 1993). This representation stage helps the problem solver determine what kind of solutions or strategies are useful. Finally, the problem solver evaluates the perceived success of the solutions against the problem goal.

Although the problem solving process as discussed above can be applicable to general problem solving, it may not be appropriate in all problem solving situations. Some problems do not have a well-known, definable solution approach (e.g. composting music or solving insight problems). Since problems often require conversion of thinking or a totally different perspective to be solved, the problem solver may be misled by applying the general rules of problem solving based on previous experiences.

Wallas (1926) presented incubation as the essential process of creative problem solving. Creative problem solving was claimed as involving four process stages: preparation, incubation, illumination, and verification. In the preparation stage the problem solver applies skills or knowledge to a new problem. The problem solver may sometimes be successful in applying known skills or knowledge to the problem in this initial attempt. However, when confronted by a failure on a problem, the problem solver often intentionally or unintentionally diverts his/her attention from the problem at hand by focusing on another activity; this divergent activity period comprises the incubation stage. While the problem solver is focused on this other, subsequent task, a moment of illumination is often encountered. Illumination refers to the experience that an insight flashes into consciousness resulting in a return to the problem solving task. Finally, this new insight is judged in its effectiveness in the subsequent verification stage. The current study is focused on the role of the incubation stage in problem solving.

In summary, it appears that there are two generally dominant perspectives that address the process of problem solving. Although both views are basically compatible with John Dewey's ideas, they appear to differ from each other in relation to the types of problems on which they focus. The views of Anderson (1993) and others (Hayes, 1988; Newell & Simon, 1972) seem to be more applicable to the processes involved with solving well-defined problems. On the other hand, Wallas' view is focused more on the processes concerned with the types of problems that we generally assume to involve insight; thus their solutions are more likely to benefit from an incubation period.

Incubation in Problem Solving

Since Wallas (1926) introduced incubation as an essential stage of creative problem solving, incubation has become an important research topic. The importance of incubation has been represented by earlier Gestalt psychologists who viewed incubation as the result of unconscious processing. For example, Poincare viewed incubation as a stage of cognitive processing controlled by a Freudian subconscious self (Stokes, 2007). During the creative processes, ideas are combined in novel ways and this combination is performed largely unconsciously. Put another way, Gestalt psychologies believed problem solving involves a flash of awareness of a solution; when this flash occurs during another activity it is considered to be the same as incubation.

Basically, expanding the ideas of incubation from the Wallas' original conceptualization (1926), Finke, Ward, & Smith (1992) defined incubation as the phenomenon in which the act of temporarily putting aside a problem at hand ultimately leads to a productive solution to that problem.

Recently psychologists have attempted to demystify the incubation phenomenon by explaining it in relation to memory processes (e.g., Smith and Blankenship, 1989, 1991; Smith, Ward, & Finke, 1995); Weisberg & Alba, 1981; Yaniv & Meyer, 1987). It was argued that if an individual is not successful in solving a problem, it is because he/she could not access the appropriate cognitive activity crucial to the solution to the problem. Either taking a break or engaging in an irrelevant task allows incubation to occur, leading the problem solver to a solution to the problem at hand; i.e., focusing on something other than on the problem at hand for a while helps the problem solver recall the relevant memory and finally solve the problem.

Research on Incubation

Research on incubation typically involves presenting an initial problem solving situation, then an interrupting session with a break or an unrelated task, and then a return to the problem solving situation. Performance change from the initial to the final problem solving session is then compared across groups. The experimental conditions typically include a control group and single or multiple interruption (treatment) groups. The interruption groups engage in an incubation period after the initial problem solving task but the control group does not. During the incubation period, the treatment groups may engage in an unrelated task or simply have break time. Some research includes multiple interruptions during the incubation session to examine the effects of different types of interruptions on problem solving. Evaluation of performance is assessed using such problems as the Remote Associates Test (RAT) problems, rebuses, or anagrams. Typically such research examines subject performance only as final written products or artifacts.

One area of incubation research has focused on fixation as an explanation for the temporary inability to solve a problem. Fixation studies examine how an incubation period impacts recovery of problem solving ability from a memory block. In such studies, subjects are presented with initial problems, and then they are provided with a deceptive, inappropriate clue to induce fixation. Smith and Blankenship (1989; 1991), in their fixation studies, reported that only the fixation induced group benefited from the incubation period.

The conceptualization of fixation in Smith and Blankenship' studies, however, seems to be restricted to address the general matter of fixation in problem solving. In those studies, fixation is induced in the subjects by the researcher rather than self-induced by the subjects. More research is needed to examine how the self-induced fixation is created and how it is removed due to an interruption activity. The use of a computer-based assessment method may help in this quest.

Methods to Assess Problem Solving and Incubation

In assessing cognitive phenomena associated with problem solving, conventional paper-pencil types of assessments can only provide information about subjects' final outcome or the correctness of their last responses. Thus, the conventional assessment format does not allow researchers to obtain information about the subjects' interaction with the problems over time. Therefore, assessments in conventional research have a limitation in describing the subjects' overall problem solving process.

Alternatively, the *think-aloud* method has been employed to examine thinking processes in problem solving. The method of think-aloud (Newell, & Simon, 1972; Ericsson & Simon,1993) has distinct advantages over the paper-pencil types of assessments in that it allows researchers to obtain information not only about the final result of problem solving but also about the learner's thinking process underlying the problem solving activity. In this approach, participants are requested to report all ideas or thoughts that come to mind while interacting with a problem. This method, however, has a limitation because it demands dual cognitive duties from the participants. The participants have to work on the problem while simultaneously providing an oral description of their actions. During this process, it's possible that the limited capacity of short-term memory would not allow the participants to remember all ideas or thoughts that would come to mind while interacting with a problem.

In comparison, computerized methods, including the technique in this current study, make it possible to accurately and unobtrusively track and record actions and subjects' progress throughout the problem solving activity. A computerized tool also provides the ability to record and summarize diverse types of data: response latencies, speed, accuracy, number of attempts, confidence levels, and a record of self-correction activities (Johnson, 1982; Kwon, Goetz, & Zellner, 1998; Zellner & Yoo, 2004). In addition to quantifying such response components, the data from the computerized tools may also include stages of subject products to show its progressions. The forms of data may be in text, numbers, sequential screen images, or even movies of subjects' screen activities. This computer-based method would also allow more careful qualitative observation of the subjects by the test administrators because it frees them from other maintenance responsibilities that paper-pencil testing formats would demand (e.g. distributing/managing testing material and providing instructions).

Overall testing on a computer also offers benefits related to replicability, accessibility, cost, and time administration compared to traditional formats (Zellner & Yoo, 2004). Subjects at a distance can easily access the testing material, participate, and submit their responses through an established online server. The data gathered can be copied as multiple computer files, and then be made accessible either to researchers or evaluators at a distance. Cost can be saved since replication of the test material would require no additional physical resources.

Computer-administered testing tools are also efficient in distributing the collected data via the internet to evaluators at various locations or placed on servers for analyses. Ultimately, this distribution capability will enhance both the opportunities for research of problem solving as well as the accessibility of any resulting data. Since computer-administered testing instruments can control all timing and sequencing of events and associated materials, they would consequently serve to increase replicability and standardization of the administration procedures.

The present study proposes a unique method that enables computers to monitor subjects' performance during the problem solving process. The computerized technique in this study further allows random assigning of subjects to an experimental condition, guiding subjects through the experiment process, and providing group specific problem or activity materials to be automatically presented at the appropriate phase of the study.

This proposed method is expected to allow more close examination of the mechanism of incubation in problem solving. With this program it is possible to simulate interaction with the problem components and functions; dynamic interactive interfaces allow subjects to manipulate the problem components as they desire. As the subjects control actions on the computer screen, the program records the action type, time, sequence, and can even evaluate correctness. This makes it possible to track time utilization and response patterns over time and compare the performance of specific groups. Two surveys that are integrated to the computerized program also record data about subjects' demographic information and their perception of the effects of the incubation activities on their problem solving activities. All data collected by the program is internally managed in relation to group placement, sequence of activities, activity type, etc. Through detailed examination of the data, behavioral patterns considered to be associated with fixation and insight could be further examined. Consequently, this approach may provide insights into ways to assist problem solvers so that their efforts can become productive and creative.

In summary, the need for a new data collection method was proposed for future work in research areas focused on examining cognitive processes. Current computer technology provides a sophisticated, on-going monitoring of subjects' interactions with the problem materials. The current study introduces such a computerized technique developed to examine the effects of interruptions on problem solving.

Features of the Computerized Instrument

The computerized research management instrument utilized in this study was developed in conjunction with a faculty member in Texas A&M University using Revolution (an object-oriented programming software). Revolution was used because it allowed robust, yet relatively simple and intuitive programming. Developing procedures for the computerized instrument involved conceptualizing and prototyping each activity, testing the usability of the resulting resource, gathering user feedback, and revising the system. Ten graduate students helped identify potential technical, procedural, or conceptual errors. Materials were reevaluated after each revision. For example, the coin problems were modified to overcome the problem in which a coin initially could be passed through other coin. This function was not true to the real-world coin problem conditions and requirements. Consequently a collision detection technique was incorporated. Moreover, the chain linking problem had been changed to function more like a simulation of the real world task. Previously, components of the chain problem could not be moved or unlinked from others. With the modification, it was possible to separate or move the link objects, either in groups or separately, simulating more closely the real world interaction with the chain links. Based on users' input, the locations for the submission and reset buttons were reconsidered and adjusted. Several buttons were also relabeled so that their usage would be more intuitive. The problem instructions that had been identified by the users as being unclear were reworded or elaborated with a visual description to ensure that the participants would fully understand the nature of the problem to be solved.

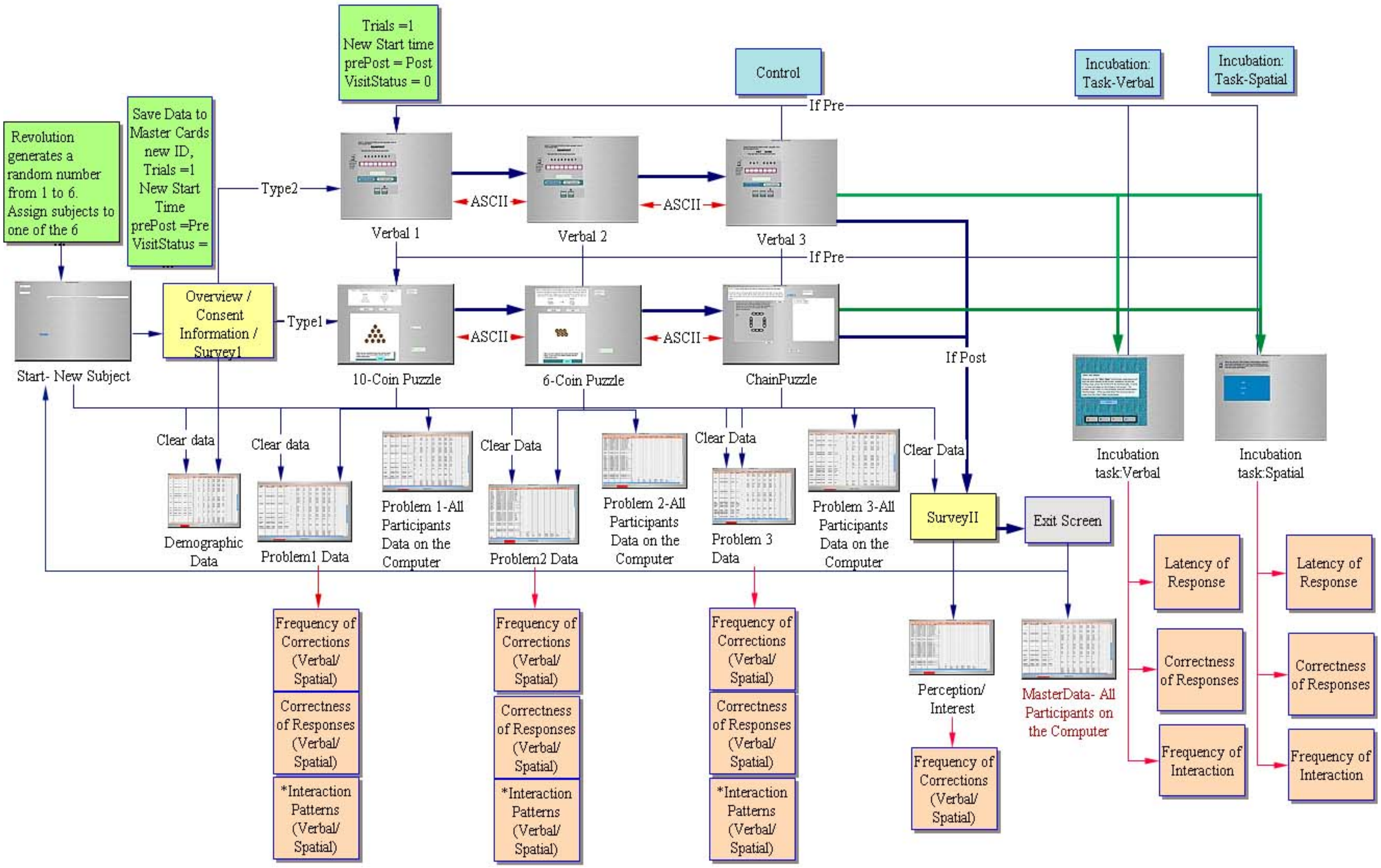
Structure

The computerized instrument was sequenced to meet the design focused on examining incubation effects and potential interaction between problem type and interruption type. Specifically, this instrument was structured aiming at a two [spatial and verbal problems (anagrams)] by three (No Task, Verbal Interruption Task, and Spatial Interruption Task) between-subjects design. It was sequenced to serve six group combinations; two control groups [spatial problems/No Task and verbal problems (anagrams)/No Task], and four treatment groups (spatial problems/Verbal Interruption Task, spatial problems/Spatial Interruption Task, verbal problems (anagrams)/Verbal Interruption Task, and verbal problems (anagrams)/Spatial Interruption Task).

The computerized instrument consisted of three parts. The first part was dedicated to the covert random assignment of the subjects to an experimental condition, a brief introduction to the experiment, and a short demographic survey (see Appendix B). The introduction covered subjects' right to decline their participation anytime during the experiment (see Appendix C), and guidance to the usage of the interactive buttons (see Appendix D). The survey collected input related to major, academic level, gender, and age. The data was saved onto the system and also in an external data file.

The second part of this program consisted of the series of problem solving activities and interruption tasks. Participants advanced through a preset series of problems, but could revisit any prior problems anytime during the problem solving session. Movement was controlled by navigation buttons placed at the bottom of each problem page. The button options were adjusted according to the relative position in the sequence. When the initial problem solving period was over, the instrument either returned the same set of problems that were presented in the initial problem solving (the No Task condition) or provided an interruption activity. The interruption task conditions consisted of a verbal interruption task and spatial interruption task. The last part of the program was dedicated to a survey of questions focused on gathering participants' perceptions of their experience with the computerized activities (see Appendix E). Specifically, the survey questions focused on the participants' perceptions of the problem solving activities and how the Interruption Task subjects thought the incubation session influenced their problem solving. See Figure 1 for the details of the program structure.

FIGURE 1. Structure of the final problem showing the progression of tasks and data storage.

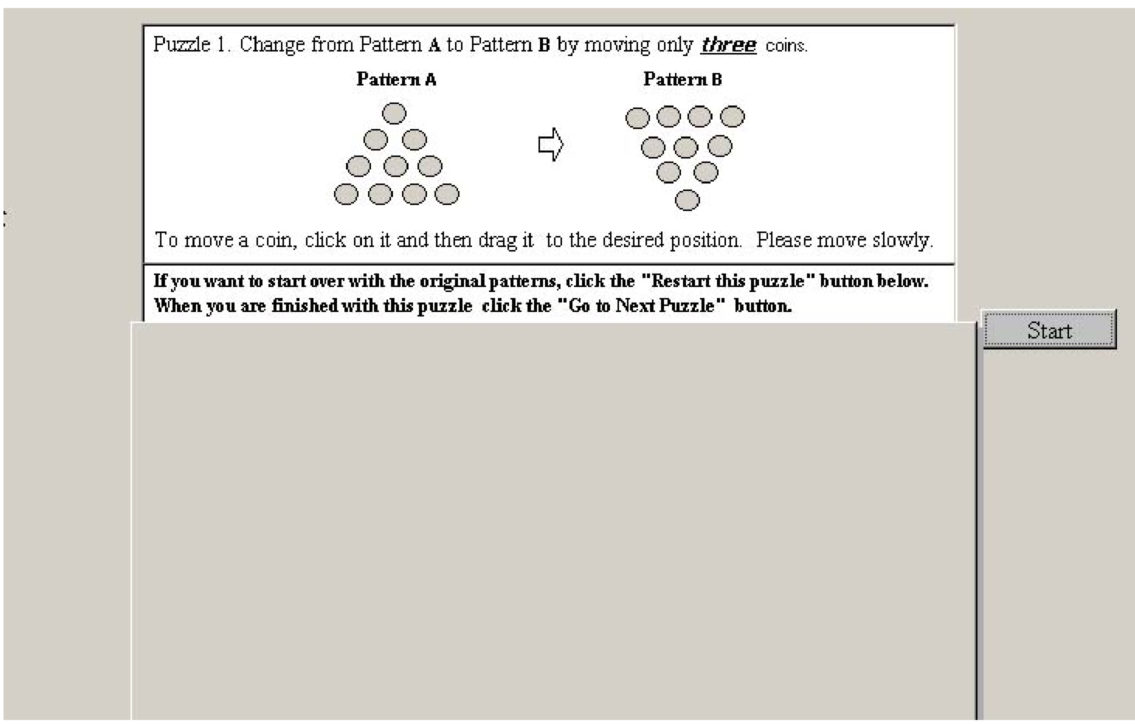


Dynamic Problem Interfaces

Spatial problems

The spatial problems consisted of three pattern transformation problems. A maximum of seven minutes were allowed to complete these three problems. Each of the problems was initially presented with only the introduction portion of the problem shown as seen in Figure 2. When the subjects were ready to begin each of the problems, they clicked the start button located just blow the instructions. The subjects' start time was recorded. The instrument then displayed the entire problem activity area (see Figure 2). The subject could restart the problem at any time by resetting the problem components using the "Restart the Puzzle" button. Whenever a subject clicked this button, the instrument counted this as a new trial and cumulatively recorded the button label, beginning time, ending time, and total counts of trials and returned the screen display to its original arrangement. When the subjects finished the problem solving activity, or wanted to stop trying and move to another activity without completing the current one, they pressed the button labeled ‘‘Go to Next Puzzle.’’ This action commanded the instrument to summarize all interactions made by the subject since his/her clicking to start that problem. This created internal data such as action sequence, activity type, time, counts, and correctness and saved them as an external file as well. The subjects could also navigate back to and modify any preceding problems using the navigation panel located at the bottom of the screen (see the bottom of the Figure 3). As a subject revisited and modified a problem, new data were added to those already collected for the problem. The display of the navigation panel adapted to the subjects' interaction as they moved back and forth in the problem sequence. It showed the current problem and any other problems that had been worked on. The navigation panel also visually reminded the subjects of which problem they are currently working on. A triangle icon was displayed over the button showing the current problem.

FIGURE 2. The 10-coin problem at the start. Initially the subjects are presented with the introduction portion of the problem. The start button leads them to the entire problem area.



The first spatial problem was the 10-coin problem (Metcalfe, 1986). The subjects were presented with an array of 10 coins arranged in a specific pattern. The subjects were then asked to change the original coin pattern (Pattern A in Figure 2) to the goal pattern (Pattern B in Figure 2) making only three moves. The problem interaction area was positioned immediately below the problem descriptions. In this area, a player could move each object by clicking on it and dragging it to a desired position as in real world conditions. The player could move a coin around another coin but could not move a coin through another coin (See Figures 3 and 4).

FIGURE 3. The 10-coin problem. Subjects are asked to transform the original pattern (A) to the goal pattern (B) in only three moves.

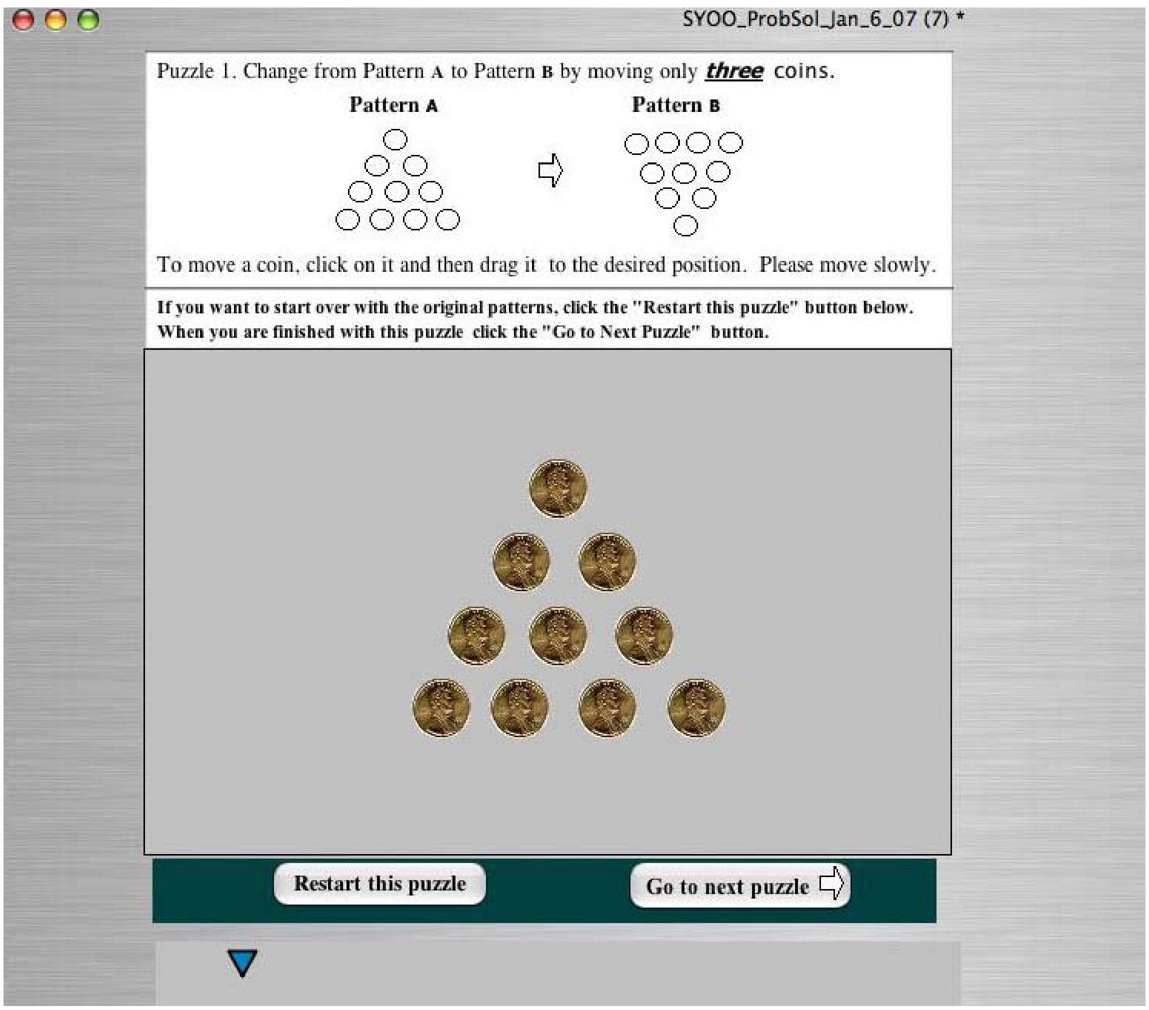
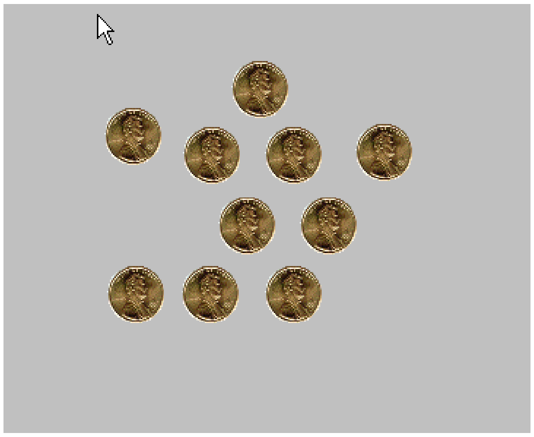
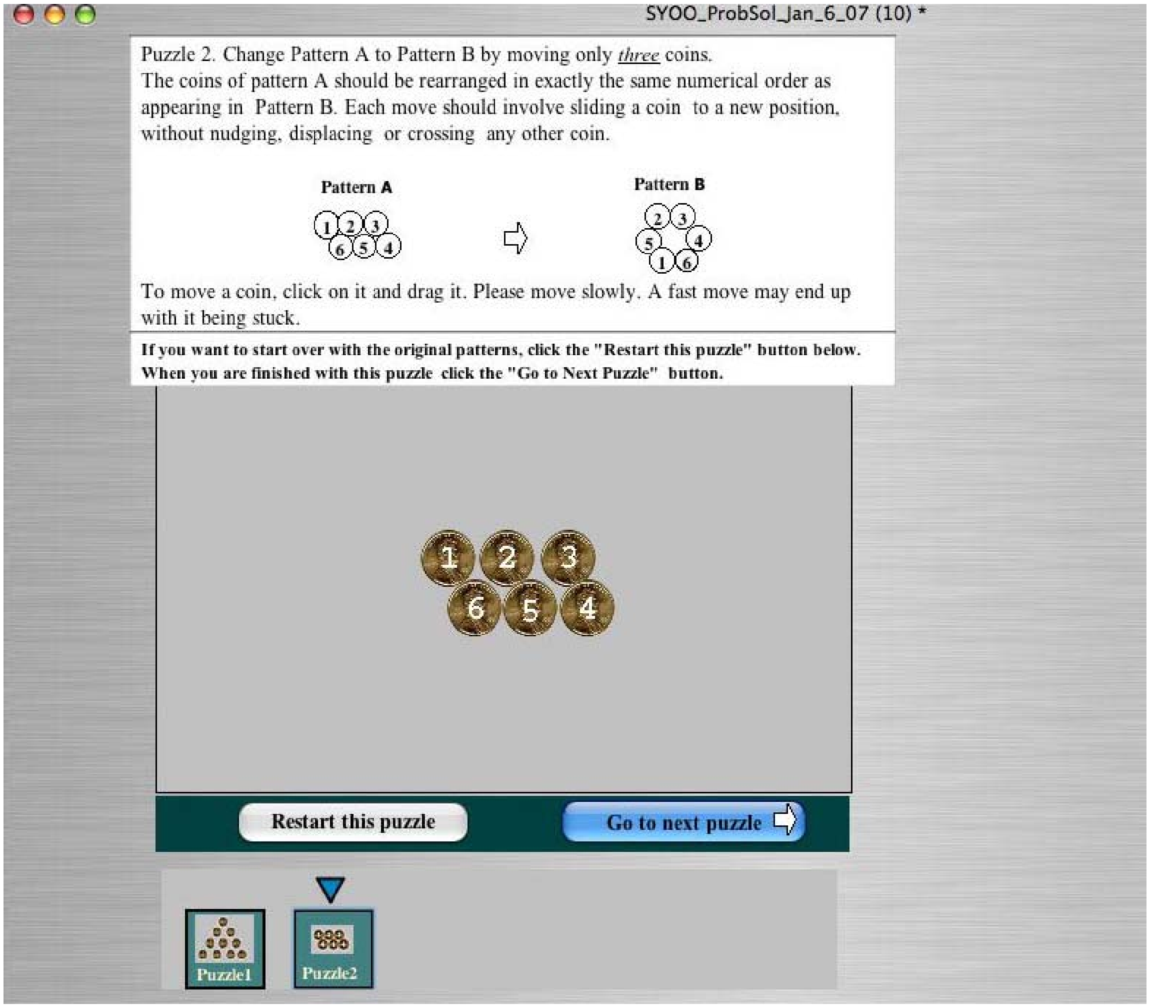


FIGURE 4. Example of solving the 10-coin problem in progress. Each coin object could be moved independently.



The second problem in the spatial problem sequence was the 6-coin problem (Chronicle, MacGregor, & Ormerod, 2004). The subjects were asked to rearrange the 6-coins in two offset rows to the 6-coins in a circle by moving only three coins. This problem differed slightly from the 10-coin problem in that each move involved sliding a coin with constraints: a) Other coins should not be disturbed or nudged during the move, and b) the coin being moved had to come to rest touching exactly two other coins. The problem solver was also supposed to arrange the coins in a specific order according to the numbers labeled on each (See Figure 5 and Figure 6). The player could revisit and modify the preceding problem using the navigation button located at the bottom of the screen.

FIGURE 5. The 6-coin problem. Subjects are asked to transform the original 6 coin pattern of two offset rows (A) to the 6 coin circle pattern (B).



The last problem in the spatial problem sequence was the chain linking problem (Finke, Ward, & Smith, 1992). The subjects were asked to connect the initial four chain parts to form one completed round chain by opening ("cutting") and attaching only three chain links (See Figure 7). The Subjects could "cut" and move each link in the problem, either alone or together with other components, using the interactive buttons: "Cut", “Separate Cut Link”, and “Move” (see Figure 8). The subjects could start the problem solving activity only after they clicked the button, “How to use the buttons”, and read the content about the usage of the buttons. When the subjects were finished with arranging the chain segments, they were also requested to describe a strategy that they might employ to solve this problem in the text area located on the right of the problem page. The ways to restart, access to other problems, or submit were identical with those for the preceding problems.

FIGURE 6. Example of solving the 6-coin problem in progress. Each coin object could be moved independently.

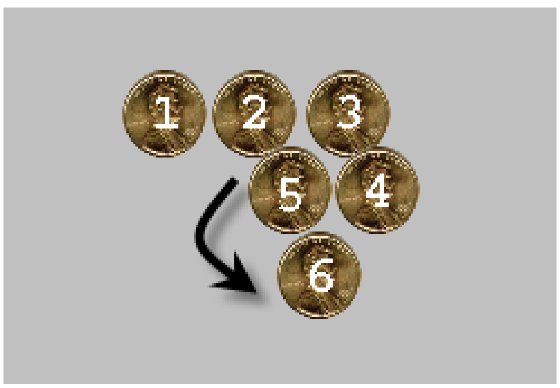


FIGURE 7. The chain connection problem. The subjects are asked to connect the four chain parts to form one completed round chain by opening and attaching only three links.

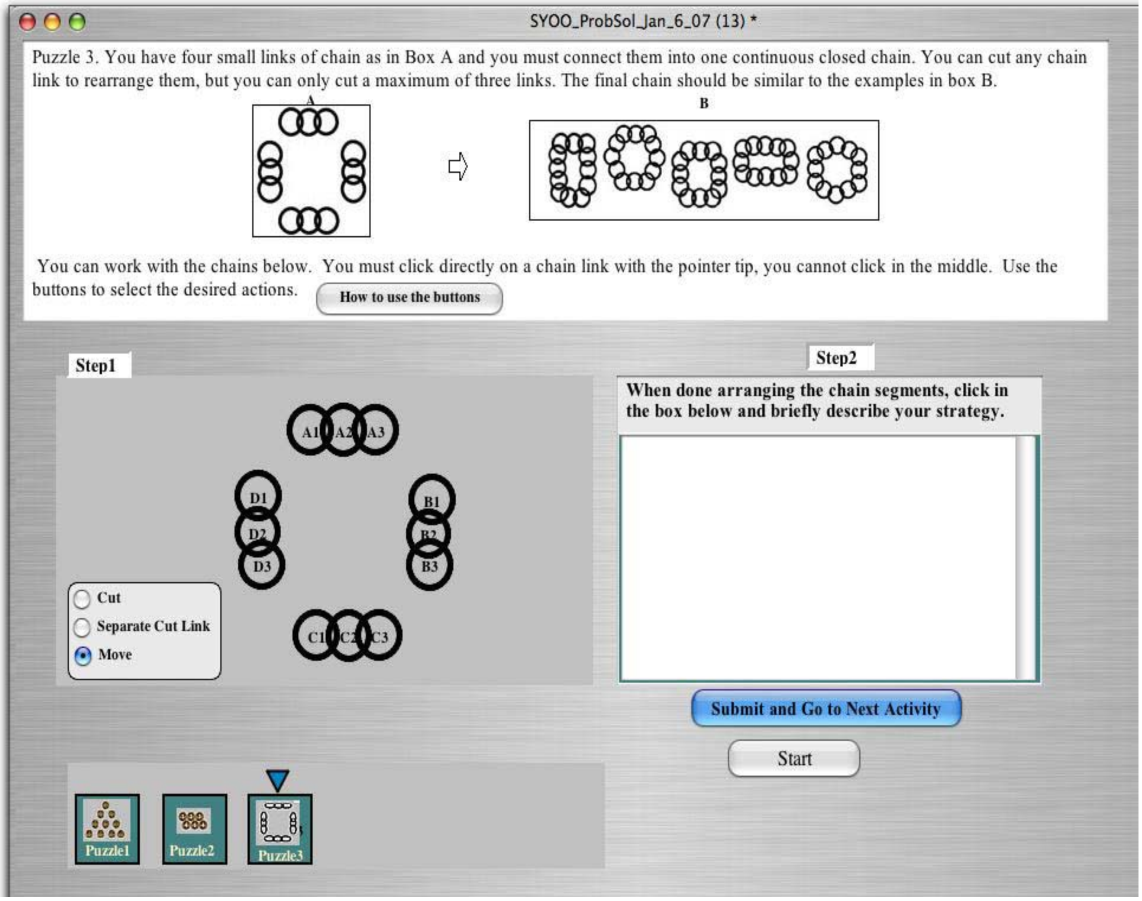
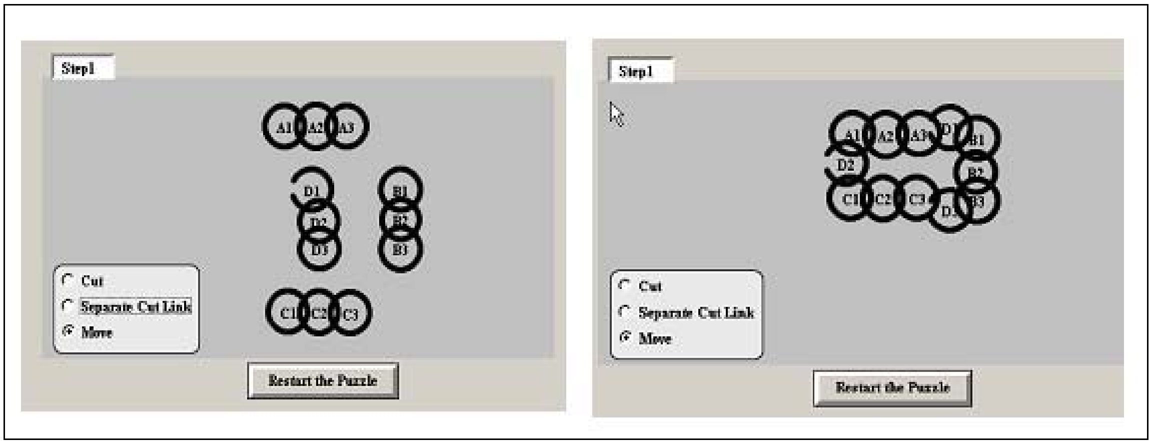


FIGURE 8. Examples of solving the chain connection problem in progress. The Subjects could cut/open and move each link in the problem, either alone or together with other components, using the interactive buttons in the left corner of the screen.

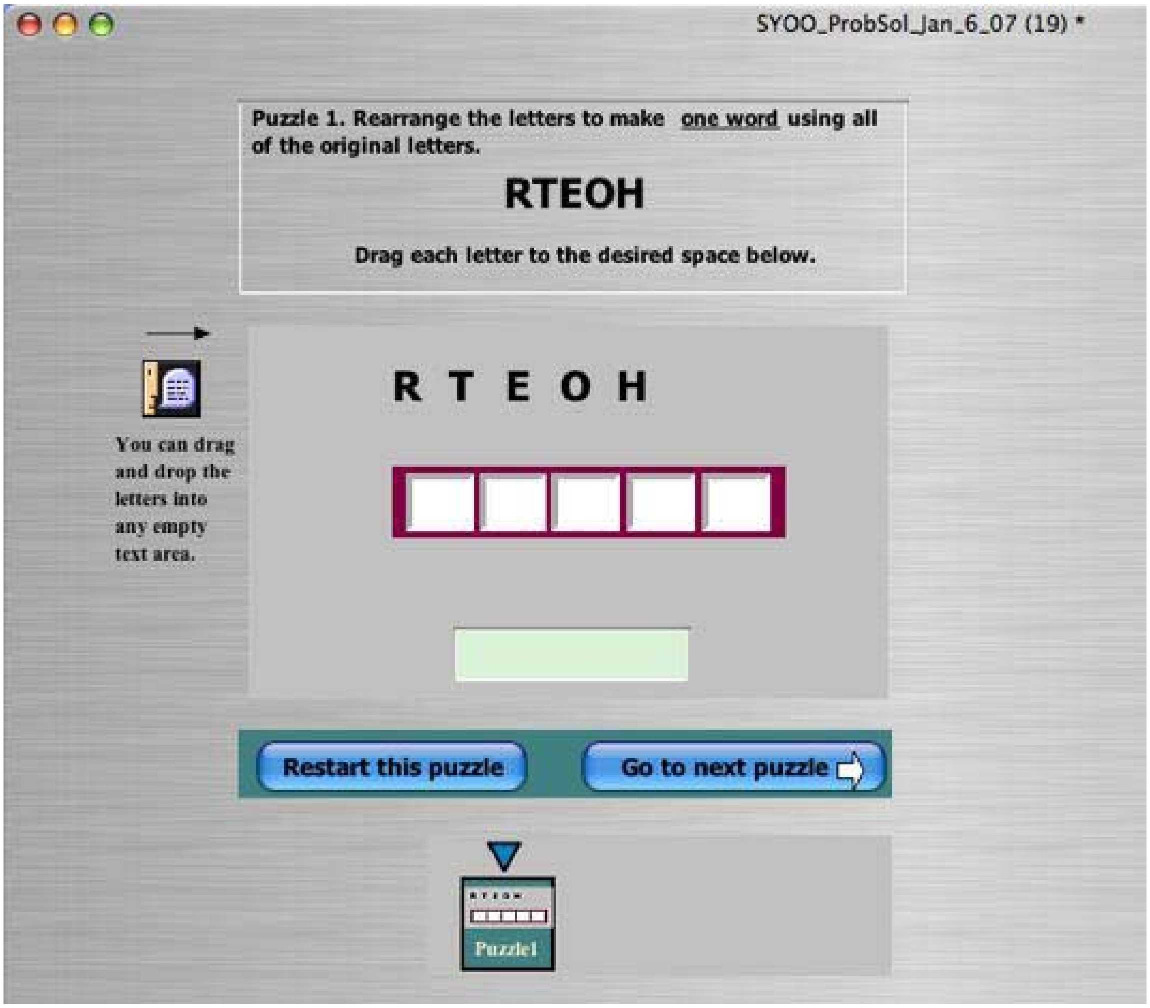


Verbal problems (anagrams)

The verbal problems were composed of three anagram puzzles. The subjects were asked to create a word by rearranging the given letter components. A maximum of five minutes were allowed to complete these three puzzles. The puzzles were presented just as the spatial problems. The puzzles were initially presented with only the introduction portion of the puzzle shown. When the subjects were ready to begin each of the problems, they clicked the start button located next to the instructions. Subjects' start time was then recorded. The instrument then displayed the entire problem activity area. The subjects could move the letters to a desired position in the text area on the screen as many times as they wanted. The initial letters for the three problems were 1) RTEOH, 2) REARPOOT, and 3) PAT RUNS. Each letter component acted like an object. Thus, as the subjects clicked on the letter components, their labels were recorded in sequence.

The look and functions of the other interactive buttons were like those employed for the spatial problems. The subjects could reset/restart the activity by clicking “Restart the Puzzle” button. Upon this action, the instrument counted this action as a new trial and recorded the beginning time, ending time, and the total counts of trials, and returned the screen objects to their original configuration. When the subjects finished the problem solving activity, or wanted to stop trying and move to another activity without completing the current one, they could use the ‘‘Go to Next Puzzle’’ button. Upon this action, the instrument summarized all interactions made by the subject since his/her clicking the start button of the problems. This created data such as action sequence, activity type, time, counts, and correctness and also saved them as an external file. The subjects could access any preceding problems using the navigation panel located at the bottom of the screen. See Figure 9 for the sample interface of the verbal problems (anagrams).

FIGURE 9. Dynamic interface of the first verbal (anagram) problem. The initial letters were RTEOH.

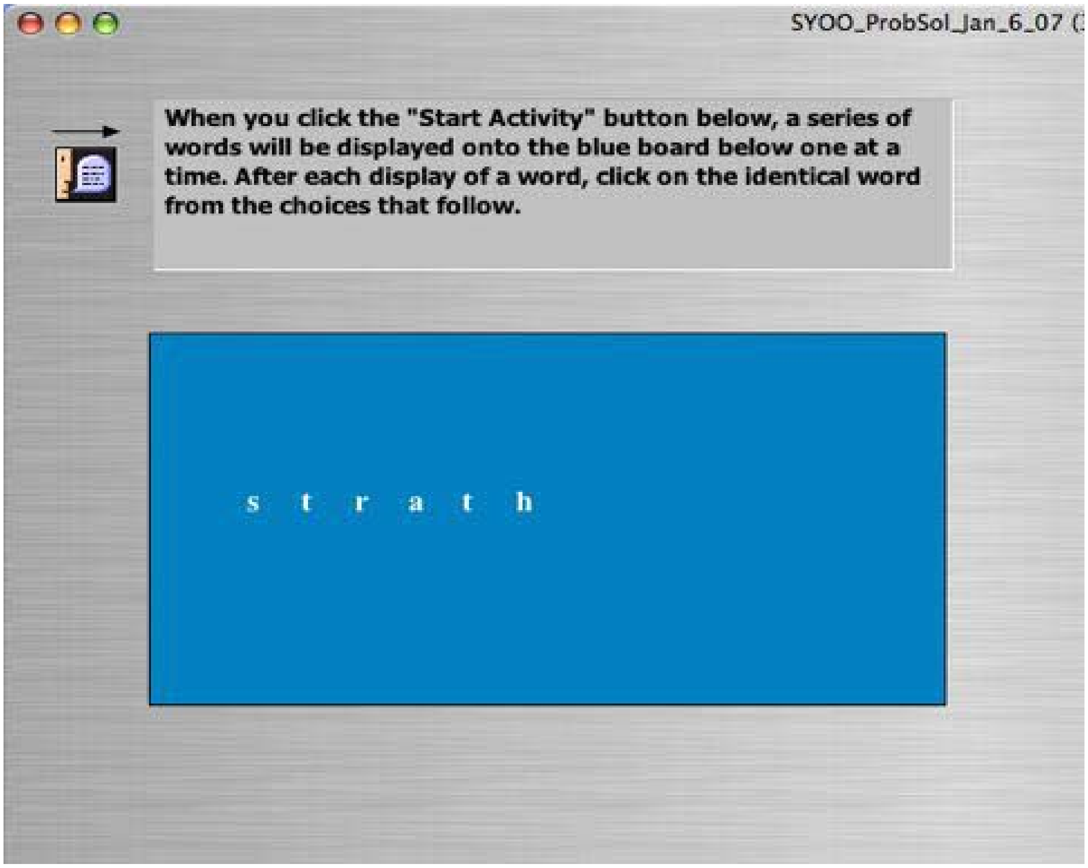


Interactive Interruption Tasks

When the participants decided to end the first session of problem solving, or the seven-minute time allotment for the session reached, the computer varied the subsequent interruption (incubation) activity according to the current subject's experimental condition; the experimental subjects were provided with either a verbal or spatial stimuli activity. Regarding the two No-Interruption groups [verbal problems (anagrams) and spatial problems], the system brought the player back to the same problem sequence that was provided in the initial problem session; the No-Interruption Task group of spatial problems began with the 10-coin problem, and the counterpart of verbal problems (anagrams) started with the anagram problem, RTEOH.

The two interruption task groups (Verbal Interruption Task and Spatial Interruption Task) for both spatial problems and anagrams were requested to work on a five-minute interruption task after the initial problem solving session. The Verbal Interruption Task group responded to a brief display of text stimuli; at intervals of two seconds a new set of white letters were projected in the middle of a blue screen composing a word; each word was randomly selected by the computer from a pool of 20 words that started with the three letter string, *str*. This similarity among the words was planned to maintain a cognitive demand. Upon seeing the letters on the screen, each subject was presented with a set of three words. The subject indicated which word he/she thought has just been flashed in the box by clicking it and then a new set of letters were flashed. This task was considered to require verbal cognitive processing. See Figure 10 for the interface of this activity.

FIGURE 10. Interface for the verbal interruption task. Upon seeing letter stimuli, the subjects were asked to identify the word that the letters formed by clicking over one from the subsequent three word choices.

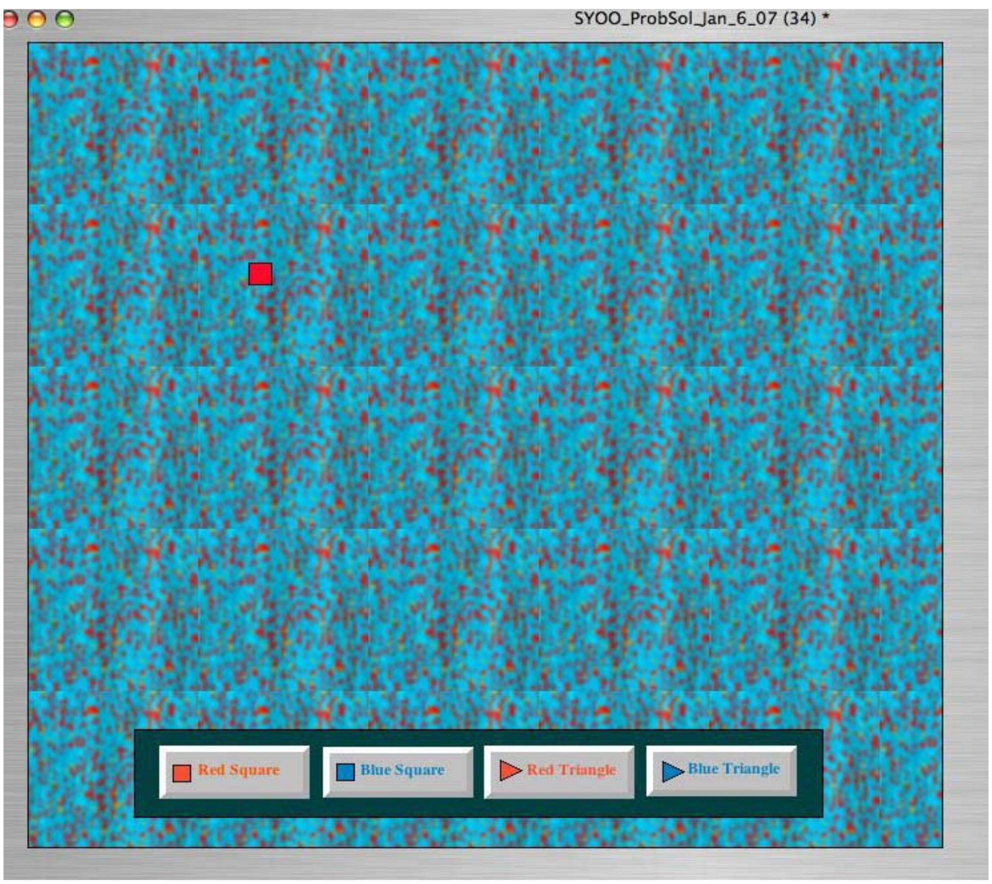


On the other hand, the computerized instrument provided spatial stimuli to the spatial Interruption Task group. Each of the stimuli was shown as a random combination of the two colors, red and blue, and the two shapes, triangle and square (i.e., a red triangle, red square, blue triangle, or blue square). The display intervals of the stimuli were randomly determined between one to three seconds. Each stimulus was displayed for one second at a random location against a somewhat visually complex screen background.

Upon seeing a stimulus (a triangle or square), the subjects were supposed to identify its shape and color by clicking the designated button (see Figure 11 for details).

When the subjects in the interruption task groups responded to the appearance of a stimulus, they clicked on the button judged to be appropriate to the object viewed. The name of the button clicked and the point in time were then recorded in the corresponding data set. When the five minute interruption period was completed, the collected interaction data set was also saved as an external data file.

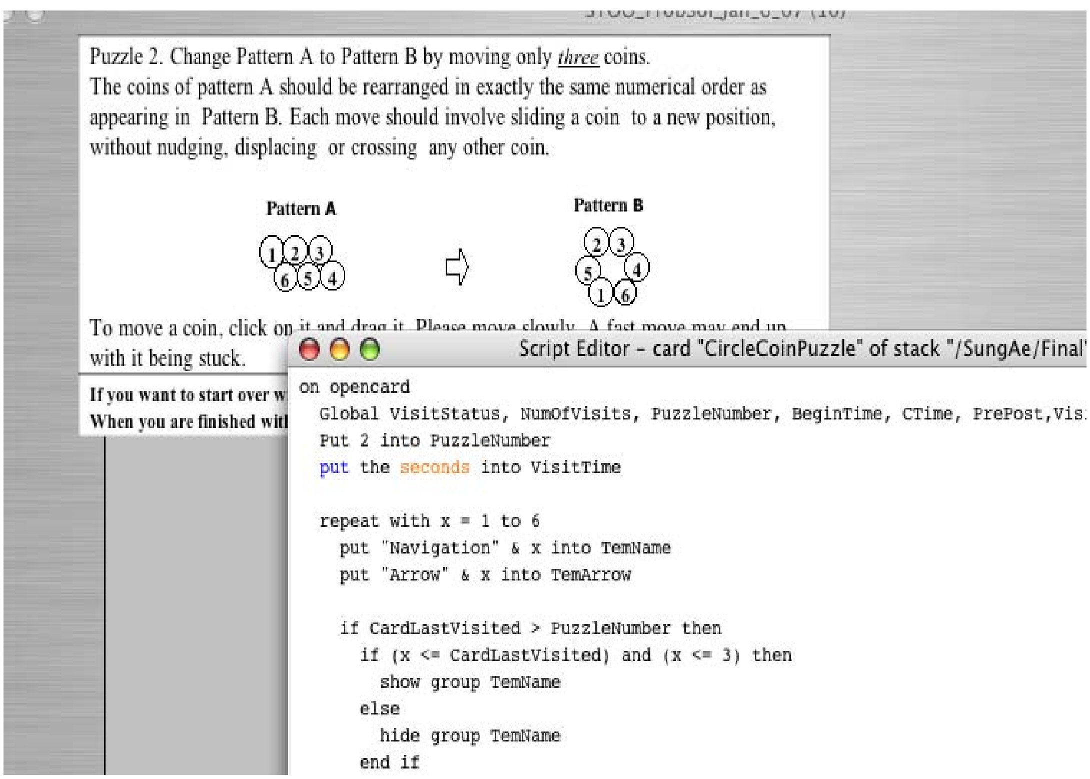
FIGURE 11. Interface for the Spatial Interruption Task group. Each of the stimuli, varied in color and shape, appeared for one second in random locations against a somewhat visually complex background.



Scripting and Recording Data

An object-oriented programming utility, Revolution, was used to develop the computerized instrument. The scripting environment of Revolution is illustrated in Figure 12. The computerized instrument was programmed to track and save all of the relevant player actions as he/she proceeded with the problem solving task. The data saved on the spatial problems included objects' names, time, locations (x, y coordinates), and interaction sequence. For the verbal problems (anagrams), data were collected as each time one of the letters was moved to record the letter name, the exact time, and the position it was placed in the word.

FIGURE 12. An illustration of typical Revolution scripting as used in the 6-coin problem.



In order to obtain information about how frequently a player retried a problem, subjects' interactions with the "Restart this puzzle button" were counted. When the player pressed the "Go to Next Puzzle" button, all data that had been recorded on the current problem were summarized and saved as an external data file. The summarized data included the names of the buttons used, the personal identification numbers, the object selection sequence, the total time used, and the trial counts (See Figure 13).

FIGURE 13. Typical interaction data from an individual who worked on the 10-coin problem.

```
Visit_pre   Exp3_C4_6_03_08_07_9_34_40 AM 3/8/07      9:38:12 AM

New pre Exp3_C4_6_03_08_07_9_34_40 AM     1173368344.4      3/8/07      9:39:05 AM  ------------
                              6     6.62   17.88      11.27 413,391     421,394     17.88 1
                              4     25.68  26.18      0.5   304,391     308,313     26.18 2
                              6     26.77  27.83      1.07  421,394     405,304     27.83 2
                              4     28.52  29.65      1.13  308,313     313,297     29.65 2
                              6     30.33  30.92      0.58  405,304     405,294     30.92 2
                              10    35.08  35.83      0.75  447,438     456,293     35.83 3
                              9     37.47  42.62      5.15  389,438     428,344     42.62 4
                              8     43.55  44.45      0.9   332,438     412,388     44.45 5
                              7     45.55  46.68      1.13  281,438     382,432     46.68 6
ReStart     1173368403.799999 3/8/07      9:40:03 AM  59.4
                              2     107.2  112.82     5.62  333,343     306,297     53.42 1
                              2     114.13 115.25     1.12  306,297     333,340     55.85 1
                              7     117.3  119.93     2.63  281,438     282,295     60.53 2
                              10    121.18 123.03     1.85  447,438     453,290     63.63 3
                              3     133.08 135.55     2.47  389,343     391,346     76.15 4
                              10    136.17 136.67     0.5   453,290     409,307     77.27 4
ReStart     1173368482.779999 3/8/07      9:41:22 AM  138.38
                              10    165.4 170.3 4.9   447,438     307,480     31.92 1
ReStart     1173368526.95     3/8/07      9:42:06 AM  182.55
                              4     203.13 203.93     0.8   304,391     291,343     21.38 1
                              7     205.68 213.45     7.77  281,438     312,393     30.9  2
                              6     218.1                               6     220.95
Submitted   1173368567.43     3/8/07      9:42:55 AM  223.03
Visit_post  Exp3_C4_6_03_08_07_9_34_40 AM 3/8/07      9:45:17 AM
```

In the sample in Figure 13, each column identifies the button name, the time, the subject identification number, the number of the coin moved, the time spent for moving the coin, the original and new locations of the coin moved, the time spent since starting the activity, and the counts of the coins used.

The subjects' performances on the interruption task were also recorded in a manner similar to those in the problem solving activities. Whenever a player clicked a stimulus or a button, the subject's identification number, responses counts accumulated, and reaction time were saved (See Figure 14). When the time allotted for the interruption task was completed or the subject terminated the activity, all data that had been recorded internally was also saved as an external data file.

Summary

This chapter introduced the computerized research management instrument that was developed to examine the effects of interruption activities on problem solving. The advantages of the program over the conventional assessment formats were discussed as including the abilities 1) to provide subjects dynamic interfaces of problems that simulate real world problem operations, and 2) to allow all data to be automatically saved internally and managed in relation to subjects' group placement, sequence of activities, activity type, etc., and 3) consequently, to make it possible for the researchers to collect information about subjects' responses, response time, interaction sequences, trial accounts, and demographic information.

FIGURE 14. Interaction data of an individual who interacted with the spatial interruption task. From the left column, the data identifies the personal identification, time, subject number, object name, response counts, time elapsed, and accumulated time elapsed.

Exp2_C4_17_04_03_07_9_56_51 AM	21	Tr	1	2.12	2.12
Exp2_C4_17_04_03_07_9_56_51 AM	21	Tr	2	1.05	3.17
Exp2_C4_17_04_03_07_9_56_51 AM	21	Tb	3	1.08	4.25
Exp2_C4_17_04_03_07_9_56_51 AM	21	Tb	4	1.05	5.3
Exp2_C4_17_04_03_07_9_56_51 AM	21	Rr	5	1.4	6.7
Exp2_C4_17_04_03_07_9_56_51 AM	21	Tr	6	1.28	7.98
Exp2_C4_17_04_03_07_9_56_51 AM	21	Rb	7	1.3	9.28
Exp2_C4_17_04_03_07_9_56_51 AM	21	Tr	8	1.1	10.38
Exp2_C4_17_04_03_07_9_56_51 AM	21	Rb	9	1.13	11.51
Exp2_C4_17_04_03_07_9_56_51 AM	21	Rr	10	1.43	12.94
Exp2_C4_17_04_03_07_9_56_51 AM	21	Tr	11	1.12	14.06
Exp2_C4_17_04_03_07_9_56_51 AM	21	Tb	12	1.23	15.29
Exp2_C4_17_04_03_07_9_56_51 AM	21	Rr	13	1.33	16.62
Exp2_C4_17_04_03_07_9_56_51 AM	21	Tr	14	1.32	17.94
Exp2_C4_17_04_03_07_9_56_51 AM	21	Tr	15	1.07	19.01
Exp2_C4_17_04_03_07_9_56_51 AM	21	Tb	16	1.82	20.83
Exp2_C4_17_04_03_07_9_56_51 AM	21	Tb	17	1.35	22.18
Exp2_C4_17_04_03_07_9_56_51 AM	21	Rr	18	1.23	23.41
Exp2_C4_17_04_03_07_9_56_51 AM	21	Rb	19	1.13	24.54
Exp2_C4_17_04_03_07_9_56_51 AM	21	Tb	20	1.33	25.87
Exp2_C4_17_04_03_07_9_56_51 AM	21	Rb	21	1.23	27.1
Exp2_C4_17_04_03_07_9_56_51 AM	21	Rr	22	1.37	28.47
Exp2_C4_17_04_03_07_9_56_51 AM	21	Tr	23	1.22	29.69
Exp2_C4_17_04_03_07_9_56_51 AM	21	Rr	24	1.22	30.91

CHAPTER III

ANALYSES OF INCUBATION EFFECTS ON SOLVING INSIGHT PROBLEMS

Introduction

Originally, the phenomenon of incubation was often understood in the forms of anecdotes of personal experiences. Archimedes' realization of how to measure the volume of an irregular shaped golden crown and Kekule's discovery of the benzene molecule are well-known example of early recognition of incubation effects.

Gestalt psychologists viewed such subjective experiences of incubation as an unconscious processing that is difficult to explain. For example, Poincare thought of incubation as a stage of cognitive processing controlled by a Freudian subconscious self (cited by Stokes, 2007). Köhler (1969) considered that the fruits of such unconscious work were experienced as a flash of awareness of a solution. It was argued that during the creative processes, ideas were combined in novel ways and this combination was performed largely unconsciously.

The concept of incubation has been popular since Wallas (1926) introduced it as the crucial stage for a creative solution to a problem. This insightful moment of finding a solution to a problem was suggested to come into existence unexpectedly while a problem solver is away from the problem at hand and is subsequently engaging in other tasks or activities. Such an interruption period during the problem solving process was labeled as incubation by Wallas (1926). It was suggested that incubation is an unconscious process. Based on Wallas' definition of incubation, Finke, Ward, and Smith

(1992) described the incubated situation as: "…a problem is set aside temporarily after an initial impasse is reached", and "the problem can then be solved more easily when attention is returned to it, or a solution may suddenly burst into the problem solver's awareness even without intentionally returning to the problem" (p.149). The current study is focused on examining the role of such interruption tasks on problem solving performance.

Recently psychologists have attempted to demystify the incubation phenomenon by explaining it in relation to memory processes (e.g., Smith and Blankenship, 1989, 1991; Smith, Ward, & Finke, 1995; Weisberg & Alba, 1981; Yaniv & Meyer, 1987). It is argued that turning one's focus to a new task rather than continuously, consciously working on the problem at hand, helps the problem solver retrieve the target information crucial for the problem solution. While either taking a break, or being involved in an irrelevant task, the problem solver may search consciously or subconsciously through the mental knowledge network for the relevant information for solving the pending problem. It is this period of alternate mental activity that helps the problem solver reach the solution.

Experimental Research on Incubation

A very limited number of studies have tested incubation effects in problem solving (Smith & Blankenship, 1991). The typical experimental approach to incubation involves interrupting the problem solving with an unrelated task or break time. Experiments generally follow the sequence:1) Have subjects engage in an initial problem solving (preparation) activity, 2) switch them to an incubation session with an interrupting activity or break time, and finally 3) have them return to the original problem solving activity or a similar set of problems. Some studies use multiple trials with multiple items (Dodds, Ward, & Smith, 2003), in which each trial on a problem has an incubation break or task. The incubation effects are measured by comparing the performance of the subjects who do not have an incubation period or task with those who engage in such an interruption task or an incubation break.

Some studies reported no effects or limited effects from incubation sessions (e.g., Dominowski & Jenrich, 1972; Gall and Mendelsohn, 1967; Goldman, Wolters, & Winograd, 1992; Olton & Johnson, 1976; Vul & Pashler, 2007). Others provided empirical evidence for incubation effects (e.g., Driestadt, 1969; Fulgosi & Guilford, 1968, 1972; Kaplan (1989); Murray & Denny, 1969; Patrick, 1938; Silveira, 1971; Smith & Blankenship, 1989, 1991; Kohn, 2005). See Appendix 1 for more details of some of these studies.

Some studies, such as Gall and Mendelsohn (1967), attempted to test the effects of particular types of activities given during the incubation periods. Their subjects worked on 30 Remote Associate Test (RAT) items for two minutes each. The control subjects then returned immediately to problems that they had failed to solve. The incubation subjects engaged in a distraction task in which they made judgments about the physical weight of items. Then the subjects were returned to the same problems. Results revealed that those in the continuous work group solved more RAT items than the interruption task groups. However, Olton and Johnson (1976) could not find differences between the control condition and the treatment conditions involving [1]eight different incubation activities. Beck (1979) tried to control for previous knowledge or experiences of the subjects with the problems used in the incubation studies by using a very novel task. He introduced subjects to a fictional new product called "luminium." Subjects were asked to list uses and qualities of luminium. Subjects in the incubation condition worked for additional twelve minutes and then relaxed or worked on an essay, some for 20 and some for 30 minutes. Finally, they returned to the luminium task for twelve minutes. Results showed the 30 minutes incubation group performed better than the 20-minute and control groups who continuously worked on the problem without a break. No difference was found between the incubation and the control conditions.

More recently, Kohn (2005) explored effects of attention levels of the activities provided during the incubation period in relation to work on RAT problems using the multiple trial approach. The study used digit monitoring tasks for the incubation conditions. The digit monitoring tasks were varied in degrees of attention required; the Low condition counted the number of occurrences of two odds in row; the Medium condition counted the number of occurrences of three odds in a row; and the High condition counted the number of occurrences of five odds in a row. The control group was told to only watch the digits closely and did not answer the number of pattern occurrences. This study implied that passive watching group or moderated level of

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[1] The eight activities included free time, demanding cognitive task (the Stroop test and counting backward), active review about the problems, set breaking, stress reduction, prominent visual analogies, unobtrusive visual analogies, and unobtrusive visual analogies plus set breaking. For more details, refer to the original article by the author.

distraction enhanced incubation effects but high level of distraction did not improved performance.

Browne and Cruse (1988) also examined if various incubation activities influence subjects' performance on the farm problem. Subjects in incubation groups worked for 10 minutes, then either drew shapes, relaxed with music, or memorized text, and returned to the farm problem to work for 10 minutes. They found that subjects who relaxed with music during the incubation were more successful than other incubation subjects. Smith and Blankenship (1989) reported four experiments that tested the effects of misleading clues on solving rebus word puzzles. They included a variety of activities during the incubation period: free time, a music perception task, rebus puzzles unrelated to the test, math problems, relaxation with a music piece, and story reading during the incubation period. They did not find effects of the intended incubation activities in any of the experiments.

In summary, the studies reported here employed a wide variety of activities to test the effects of incubation. Gall and Mendelsohn (1967) reported that subjects who developed associations to RAT items during incubation had better subsequent performance than those who made judgments about the physical weight of items. Browne and Cruse (1988) discovered that subjects who relaxed with music performed better than those who drew shapes or memorized text. The results from Kohn's study implied that attention levels of activities provided during the incubation related to degree of incubation effect. Olton and Johnson (1976), Beck (1979), and Smith and Blankenship (1989) used demanding mental tasks and found no incubation effects among groups. Base on these results, there is no clear pattern of the effects of incubation activities on problem solving.

The existing empirical findings on incubation effects appear to contradict each other making it hard to draw general conclusions about the role of an incubation period or task type in problem solving. Brown and Cruse (1988) reasoned that such inconsistency was partially due to the methodological differences and inadequate control of problem solvers' covert processes during the non-task incubation period. Inclusion of only one type of problems and/or interruption tasks in earlier research also makes it hard to compare the findings across the studies. Additionally, Vul and Pashler (2007) argued that the low power resulting from the small sample sizes in many of the previous studies may cause Type II error.

Review of the literature suggests there have been no empirical attempts to determine the possibility of interaction between different problem types and the type of interruption tasks. Studies typically employed only a single type of problems (e.g., RAT, anagrams, rebuses, dot problems, etc.). Obviously, different types of problems would not require the same cognitive processes to be solved. For example, anagrams may require more algorithmic computation compared to the rebus problems. Similarly, one type of interruption task may be influential for only some types of problems. Thus, it is possible that an incubation effect shown to be related to one type of problem may not be evidenced on another type of problem.

In summary, there appears to be a minimum of research focused on the role of interruption tasks in problem solving. Findings from the existing research do not seem to come to an agreement about the role of incubation activities in problem solving. As Brown and Cruse (1988) concluded, such contradiction evidenced among research findings may be due to the methodological differences between studies. In particular, there seems to be no empirical research focused on determining how different types of problems interact with different types of interruption tasks. The current study is intended to improve upon the designs of the past research by exploring incubation effects involving more than one type of interruption task and a large sample size.

Theoretical Framework

Types of Problems

This current study employed a series of insight problems. Insight problems have the characteristic that “the methods for arriving at the solution are often unclear” (Finke, Ward, & Smith, 1992, p.169). Bowden (1997) summarized that insight problems are distinguished from other problems by three properties: (1) When working an insight problem, the problem solver experiences an impasse due to the initial misinterpretation of the problem or unwarranted assumption for the solution to the problem, (2) the problem solver experience suddenness and surprise, and 3) with insight problems, the problem solver has difficulty reporting the processes that lead to solution.

Wakefield (1992) classified problems into four different types depending on the degree of constraint imposed on the initial and goal statues of the problems. Accordingly, the problems are classified into four types: a) closed problems with closed solutions (CC), in which there is only one possible solution constrained by clear rules and methods; b) closed problems with open solutions (CO), in which multiple possible solutions exist; c) open problems with closed solutions (OC), in which there is only one answer but ways to reach the answer are not clear, and d) open problems with open solutions (OO) where very little constraint exists to guide the solution and thus multiple answers are possible. See also Table 1. These problem types require, in order, logical thinking, divergent thinking, insightful thinking, and creative thinking. The CC problems have a well-established procedure to be solved and an agreed-upon criterion against which the solution is evaluated (are also called well-defined problems). On the other hand, the rest of the types of problems (also called ill-defined problems) probably will have more than one solution (CO or OO) or unclear procedures or methods to reach to the/a solution (OC, or OO).

TABLE 1. Wakefield (1992)’ Four Types of Problems Based on Problem Constraints.

	Solution Problem Status	
Initial Problem Status	Closed	Open
Closed	CC	CO
Open	OC	OO

Studies of incubation have included both well-defined and ill-defined problems (CC, OC, and CO). Truly open problems with open solutions (OO; e.g., composing fugue, painting, and writing a novel), however, have not been used, probably because their solutions are difficult to evaluate and could not lead to definitive results. Consequently, research on incubation has commonly included problems such as dot connection, chain link connection, coin arrangement, rebuses, idea generation, anagrams, the Farm problem, and word association. These problems are generally categorized as insight problems. Anagrams, however, are considered as either CC problems that require algorithms or heuristics or OC type of problems that require creative conversion or insight to reach a solution (Finke, Ward, & Smith, 1992).

The present study focuses on investigating the incubation effects using OC problems; particularly, this study employs three spatial arrangement problems (chain link connection and coin arrangement problems) and three anagram problems.

The Mechanism of Incubation

Recent researchers account for the incubation phenomenon as being the result of relevant solution knowledge retrieval after a period of diverting attention from the problem at hand. Yanive & Meyer (1987) conceptualized spreading activation as the underlying retrieval mechanism in an associative knowledge network. Based on this approach, knowledge is more accessible if it has been retrieved recently and the activation is then spread to other related knowledge in an associated knowledge network. The process occurs subconsciously while the individual is searching for target knowledge. This process is different from algorithmic manipulation or trial-and-error search. Activation of knowledge spreads subconsciously (e.g., *tree* activates *family*, which activates *home*) after an initial unsuccessful retrieval of knowledge. When an individual has an unsuccessful attempt while trying to solve a problem, the initially activated knowledge continues to activate other associated knowledge to reach the target knowledge required for the solution to the problem even when the person is physically away from the problem at hand. Thus, incubation is considered to be the result of the subconscious spreading activation. These accounts for incubation, however, seem to be more applicable to the association type of problems (e.g., remote association, novel association problems, etc.) than the spatial arrangement type of problems included in the incubation studies, such as dot connection, chain link connection, and coin arrangement.

Conversely, Weisberg & Alba (1981) conceptualized incubation to be not a period of total removal from the problem task but one in which some sort of residual solving activity exists; where continuous activation of memory of the problem components generates creative strategies for solving the problem. Thus, problem solvers benefit from an incubation period because they continue to work covertly on the problem during that period.

Another viable account for the mechanism of incubation is the fixation approach. Based on this approach, incubation is regarded as the result of dissipation of a fixation or a mental block (Smith and Blankenship, 1989, 1991). A problem solver may become fixated on a familiar or known approach while searching for a solution to a problem. This may be because the problem solver’s recent problem solving experiences or inaccurate assumptions about the problem solutions inhibits him/her from seeking a new approach (Smith, 1995a). An interruption, or a break, in the course of problem solving can help the problem solver abandon the familiar, inappropriate, problem solving method. This removal of fixation is asserted to result in an insightful awareness of a new solution to the problem.

Interaction between Problems and Interruption Tasks

Although an interaction between the problem types and interruption task types was considered as quite feasible, there seems to have been no attempt in the literature that focused on potential interaction. The problem type and interruption task type interaction, if any, may provide an insight into the nature of the incubation phenomenon. The present study included two types of insight problems that required different cognitive processes for their solution. One type was believed to need more verbal processes and the other type more spatially-oriented processes. The interruption tasks employed in the present study were similarly varied according to their orientation with these two processes; one type was designed to be more verbal and the other to be more spatial-visual.

Based on the potential interaction pattern that may exist between the problem types and the interruption task types, two alternative accounts for the incubation phenomenon could be examined. First, if the solving of one type of problem benefits more from an interruption task that involves the same process orientation as the problem type, it may be implied that the interruption task actually does divert the problem solver's attention from the problem solution. The problem solving task and the interruption task that are similar in their cognitive process orientation are likely to compete with each other, and thus once a problem solver switches his/her attention from the problems to the interruption task, it is unlikely that the person can continue to work on the previous problems at the same time. In the current study, if parallel combinations of the problems and incubation tasks [spatial problems-spatial interruption task, verbal problems (anagrams)-verbal interruption task] more positively affect subjects' performance, this account will be supported.

Conversely, if working on a type of problem benefits more from an interruption task that involves a different process orientation, it may be suggested that the problem solver's cognitive, covert work on the problems can more easily continue during the incubation period. In the current study if the cross-combinations of the problems and incubation tasks [spatial problems-verbal interruption task, verbal problems (anagrams)-spatial interruption task] more positively impact subjects' performance, this interpretation will be supported.

Research Questions

The review of research on incubation reveals a need for more studies focused on the role of incubation in problem solving. It was also obvious that the existing inconsistency among research findings on the incubation effects calls for more standardized research methods. Also, there seems to be no attempt to examine the potential interaction between problem types and interruption task types.

The primary intent of this study is to examine the role of incubation in solving insight problems. In the present study, incubation effects are operatively defined as improvement in problem solving performance of the participants who work on an interruption task compared to those who continue to work on the problems without being interrupted. The second intent of this study is to examine the potential interaction between the types of problems and types of interruption tasks included in this study. Two types of problems were incorporated: spatial (pattern change) and verbal (anagram) problems; and two types of interruption tasks: spatial stimuli reaction and verbal stimuli reaction tasks. Thus, interaction will be evidenced if one type of problems benefits more from only one type of interruption task.

The specific questions were the following:

1. Do the two interruption groups, combined and individually, perform differently on the final problem solving tasks from the no-interruption group (or continuous working group) on each type of insight problem?
2. Is there interaction between the two types of insight problems [verbal (anagrams) and spatial], and two types of interruptions (verbal and spatial)?

Method

Participants

A total of 202 undergraduate volunteers in Texas A&M University participated in this study. Participants were recruited from four undergraduate courses offered during the spring in 2007. The participants were enrolled in Educational Psychology, Problem Solving in Mathematics, Educational Statistics, Child Development, and Geology classes.

In recruiting, the researcher made an initial contact with the participants directly in their classroom or on-line via their class website with help from the instructors. All participants joined the research as volunteers. Participants other than those from Geology were rewarded by 2 or 3 bonus points in return for participating in this study. To manage the efficient scheduling for each participant, an on-line scheduler was set up on a web-server. The on-line scheduler site address was announced to the participants via their class web-site and/or via e-mail by the instructors. Participants then individually scheduled their participation date and time at their convenience.

Only 185 out of 202 participants were included in the final analyses. Participants whose data were considered to inappropriately represent their abilities (i.e., did not appear to actually work on the problems) were dropped out. Specifically, participants were excluded if they responded with a wrong answer (including no response) on both the initial and final problem solving, and they took less than -0.5 standardized units of time during the initial problem solving session. The eliminated subjects were equally distributed across the groups. The participants' age ranged from17 to 27. They represented the majors as seen in Table 2.

TABLE 2. Major Composition of the Participants.

Major	N	%
Education	120	64.9
Liberal Arts	25	13.5
Science	23	12.4
General Studies	7	3.8
Engineering	5	2.7
Architecture	3	1.6
Political Science	2	1.1
Total	185	100

Design and Setting

In the present research, a two [spatial and verbal problems (anagrams)] by three (No-Interruption Task, Verbal Interruption Task, and Spatial Interruption Task) between group design was used. Specifically, the experimental design had six group combinations: two control groups [spatial problems: No-Interruption Task and verbal problems (anagrams): No-Interruption Task], and four treatment groups [spatial problems: Verbal Interruption Task, spatial problems: Spatial Interruption Task, verbal problems (anagrams): Verbal Interruption Task, and verbal problems (anagrams): Spatial Interruption Task]. Only between-group comparisons were considered in order to preclude the potential confounds that a within-group design may cause (i.e., when a subject is allowed to engage in multiple conditions, it is possible that his/her current condition activity can play the role of incubation for the preceding condition activity).

The experiment was conducted during the spring semester in 2007 (February to April) in a computer laboratory in Texas A&M University. Nine Macintosh computers with the OX10 operation system were used. All participants worked alone on a computer. The computers had an identical interface except for the screen size; some of the computers had slightly larger screens.

The participants were randomly assigned to one of the nine computers upon entering the computer lab. The computers then assigned the subjects to one of the six experimental conditions; i.e., when a new subject began the program, the computer incremented a condition number between one to six in order to assign the person to that condition [number 1: spatial problems-No-Interruption Task; number 2: spatial problems-Verbal Interruption Task; number 3: spatial problems-Spatial Interruption Task; number 4: verbal problems (anagrams)-No-Interruption Task; number 5: verbal problems (anagrams)-Verbal Interruption Task; and number 6: verbal problems (anagrams)-Spatial Interruption Task]. The nine computers were programmed to each start at a different number (e.g., the first computer at one, the second at two,…, and the ninth at three) to ensure equal number of participants across the conditions. Subsequently, each subject was provided with materials and activities in accordance with the experimental condition assigned by the computer.

Thirty-minute experiment sessions were scheduled with a capacity of nine individuals each session. An average of 15 sessions per week were scheduled. Prior to working individually on the computer, the participants in each session were provided with a minimum level of oral orientation regarding the study by the researcher. The participants could ask the researcher any questions about the contents, activities, or technical aspects of the research during the session.

Procedures

Upon starting the session, the computer provided the participants with initial information about their right to decline the experiment. The computer also informed the participants of the use of the interactive buttons in the program, and the time allotted for each activity. Subsequently, the computers prompted the participants to respond to a survey designed to collect general demographic information. The participants provided academic level (e.g., a freshman), major, gender and age. (See Appendix B for the details).

The participants were randomly assigned one of the six different experimental conditions by their computers. Half of the participants worked with the spatial problems for a maximum of seven minutes for each problem solving session. The other half worked on the verbal problems (anagrams) for a maximum of 5 minutes for each session. The time limit for each type of questions was established based on the feedback from the pilot sessions that were conducted prior to the current experiment. The feedback indicated that the spatial problems needed a few minutes more than the verbal type of problems for completion, and so seven minutes were allowed for the spatial problems.

After the initial problem solving session, one third of the participants for each type of problem were assigned to the Verbal Interruption Task group. Similarly, another one third of the participants for each of the problem types were assigned to the Spatial Interruption Task group. The last one third of the participants assigned to each of the question were assigned to the control group. They did not have an interruption task. Upon completion of the initial problem solving session they were presented with an identical second problem solving session. Otherwise this group had the identical procedures of the other experimental conditions.

TABLE 3. Summary of the Sequence of the 6 Conditions.

Problem Type	Condition	Session 1	Session 2	Session 3
Spatial	1	Initial Problem Solving	Verbal Interruption	Final Problem Solving
	2	Initial Problem Solving	Spatial Interruption	Final Problem Solving
	3	Initial Problem Solving	No Interruption	Final Problem Solving
Verbal (anagram)	4	Initial Problem Solving	Verbal Interruption	Final Problem Solving
	5	Initial Problem Solving	Spatial Interruption	Final Problem Solving
	6	Initial Problem Solving	No Interruption	Final Problem Solving

The Verbal Interruption Task group responded to a brief display of text stimuli; at intervals of two seconds a new set of white letters were projected in the middle of a blue screen composing a word. On the other hand, the Spatial Interruption Task group interacted with geometric stimuli that varied randomly in color, shape, and location at intervals of two seconds. Upon seeing a verbal or spatial stimulus on the screen, the problem solver was to immediately respond to it by clicking on the associated word in a list or symbol in a set of possible combinations. When the five minutes allowed for the Interruption Task reached, the interaction data was also saved as an external data file. Read the following *Materials* section for more details of the Verbal and Spatial Interruption Tasks. See Table 3 to see the summary of the sequence of the groups.

Materials

Problems

Two types of insight problems [three spatial and three verbal problems (anagrams)] were adapted and developed as computerized problems for this study. The spatial problems included a 10-coin arrangement problem (Metcalfe, 1986), a 6-coin arrangement problem (Chronicle, MacGregor, & Ormerod, 2004), and a chain connection problem (Finke, Ward, & Smith, 1992). The verbal problems (anagrams) consisted of 3 items; one problem was adapted from Finke, Ward & Smith's book (p.172) and the other two were created for this study.

The first question of the spatial problems was the 10-coin problem. Subjects were presented with a display of coins arranged in a pyramid pattern and then asked to change the coins from that original pattern (Pattern A in Figure 15) to the goal pattern (Pattern B in Figure 15) by making only three moves.

FIGURE 15. Screen display from the 10-coin problem. Subjects were asked to transform the coins in the original pattern (A) to the goal pattern (B) in just three moves. Each coin could be moved independently.

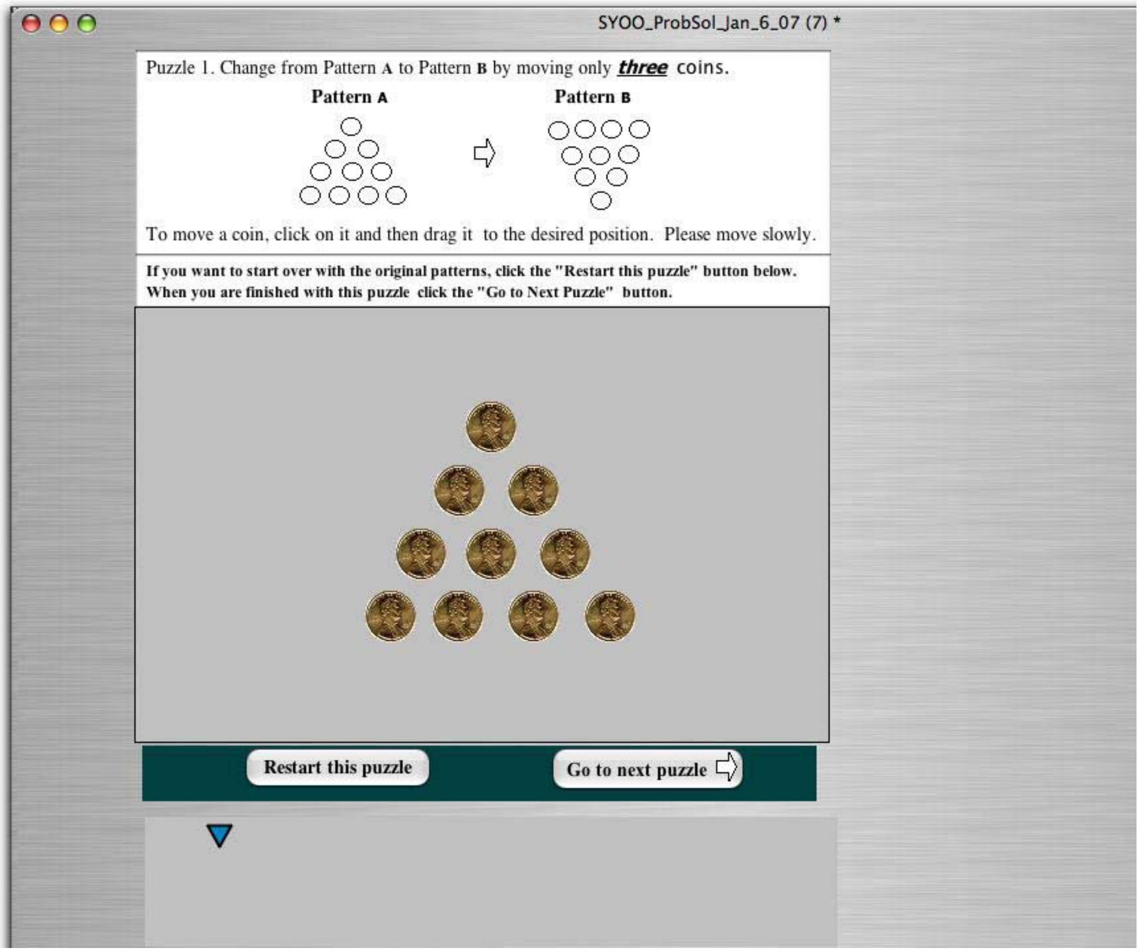
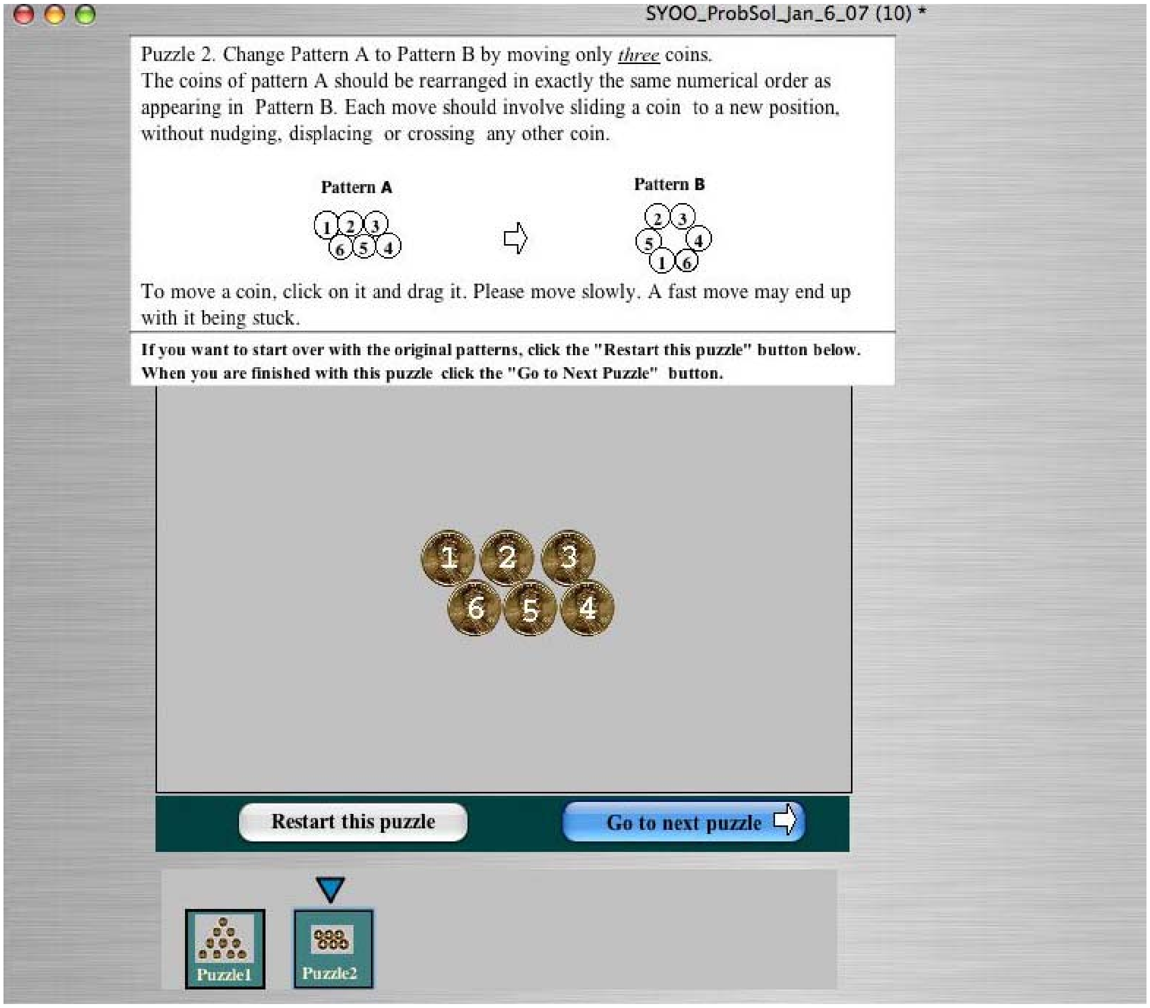
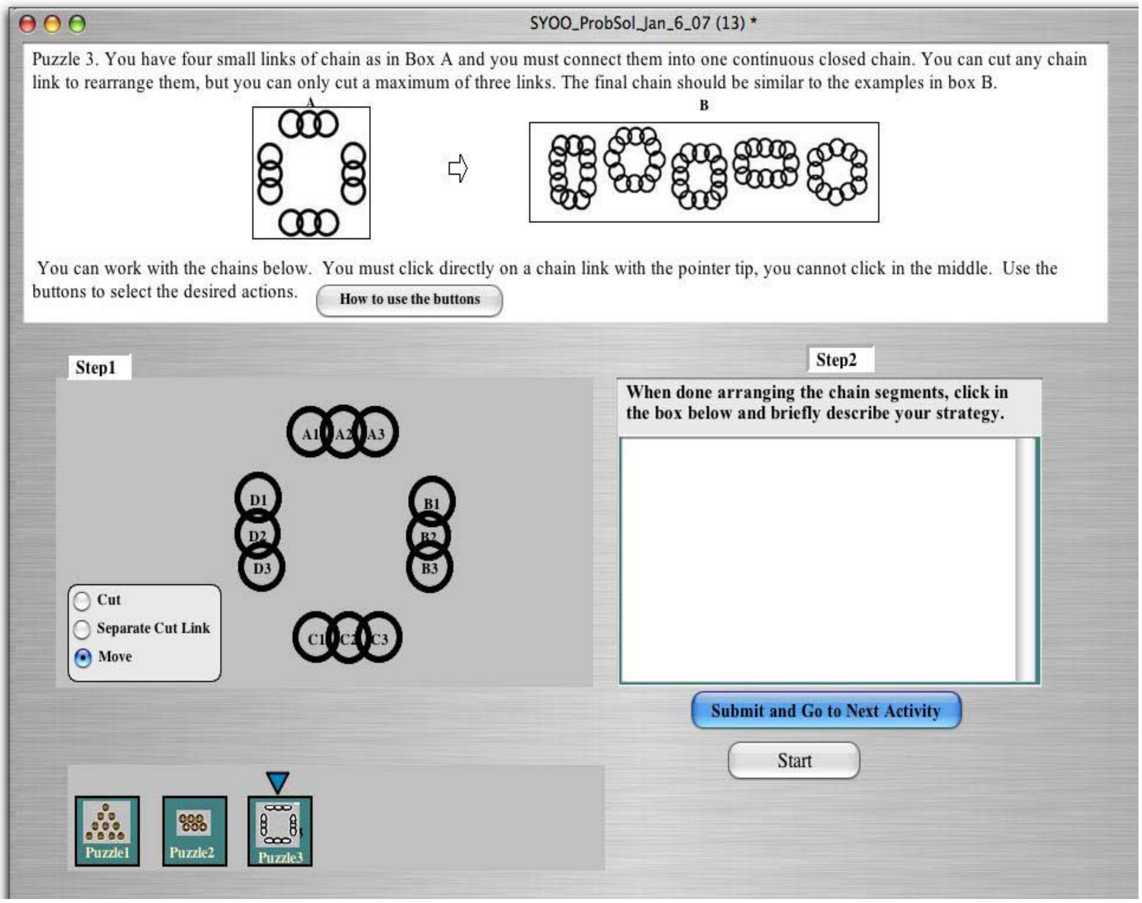


FIGURE 16. Screen display from the 6-coin problem. Subjects were asked to transform the original 6 coin pattern of two offset rows (A) to the 6 coin circle pattern (B). Each coin could be moved independently.



The second question of the spatial problems was the 6-coin problem. This problem was very similar to the 10-coin problem in that it also involved transformation of an original pattern (6 coins in two offset rows) to the goal pattern (the 6-coins in a circle) by making no more than 3 moves. However, this problem differed in that each move involved sliding a coin with constraints: a) Other coins should not be disturbed or nudged during the move and b) the coin being moved had to come to rest touching exactly two other coins. The problem solver was also required to arrange the coins in a specific order according to the numbers labeled on each (See Figure 16).

FIGURE 17. The screen display from the chain connection problem. The screen components consist of problem description area, interaction are, and progressive menu.



The last question of the spatial problems was the chain linking problem. Subjects were presented with a display of four parts of chain links. To solve this problem subjects should connect the four chain parts to form one single completed round chain by opening and attaching only three links. Subjects could open and move each link in the problem using the designated buttons (i.e., the buttons named “Cut”, “Separated Cut Link”, and “Move”, were used to cut, unlink or move the chain components). See Figure 17 for details.

For each of the verbal problems (anagrams), the subjects were presented with a set of letters and requested to arrange them to spell the correct word. They could try to sequence the letter objects by dragging and dropping them into the designated text fields on the screen as many times as they wanted. The initial letters were 1) RTEOH, 2) REARPOOT, and 3) PAT RUNS. See Figure 18 for the example interface of the verbal problems (anagrams).

Interruption Tasks

Verbal Interruption Task. The Verbal Interruption Task group interacted with a brief display of text stimuli; at intervals of two seconds a new set of white letters were projected in the middle of a blue screen composing a word; each word was randomly selected by the computer from a pool of 20 words that started with the three letter string, *str*. This similarity among the words was planned to maintain a cognitive demand. Upon seeing the letters on the screen, each subject was presented with a set of three words. The subject indicated which word he/she thought has just been flashed in the box by clicking it and then a new set of letters flashed. Since the word options were displayed for only one second, the participants had to be vigilant. This task continued for 5 minutes (see Figure 19 for details).

FIGURE 18. Dynamic interface of the second anagram problem. The initial letter set was REARPOOT.

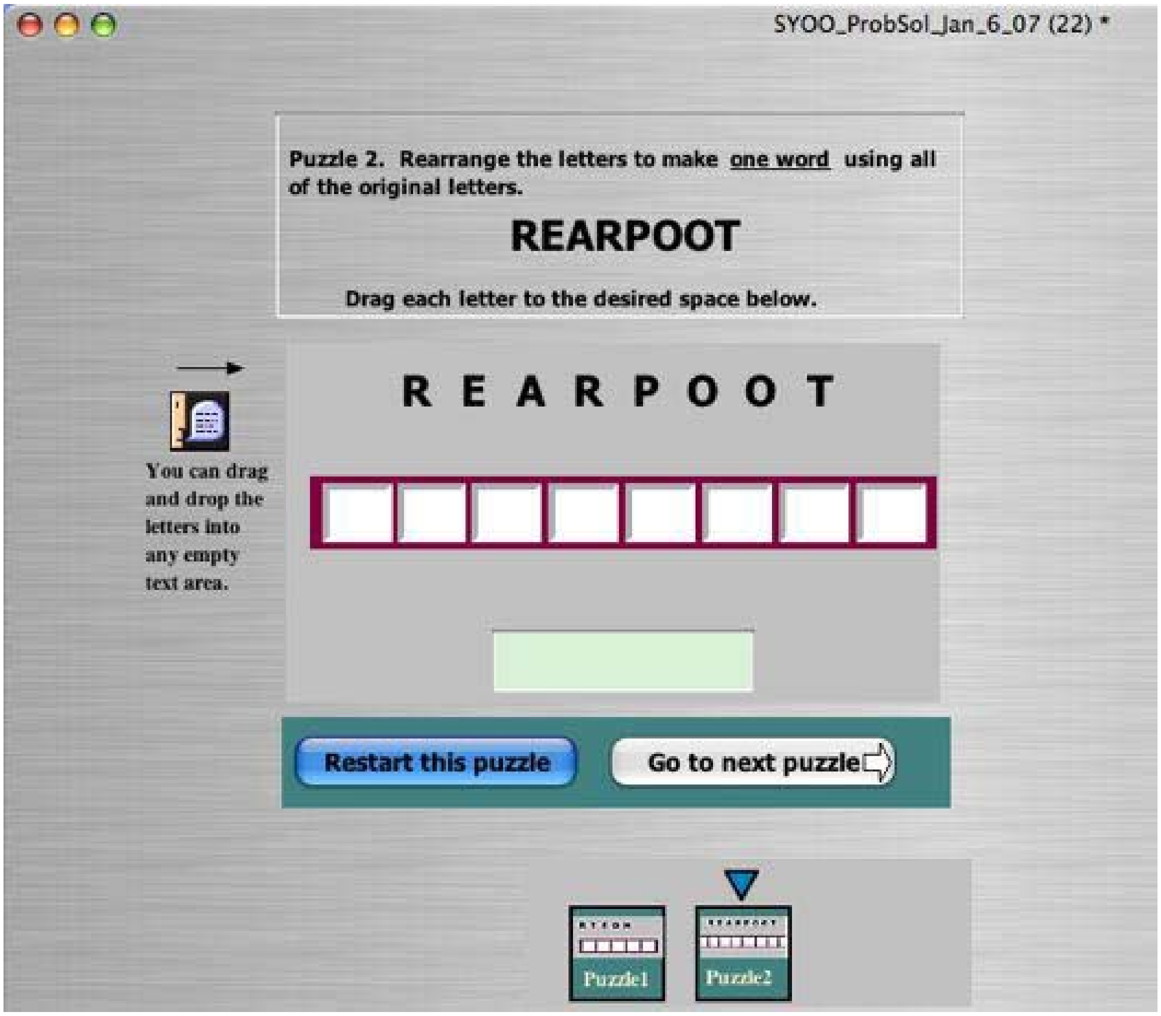
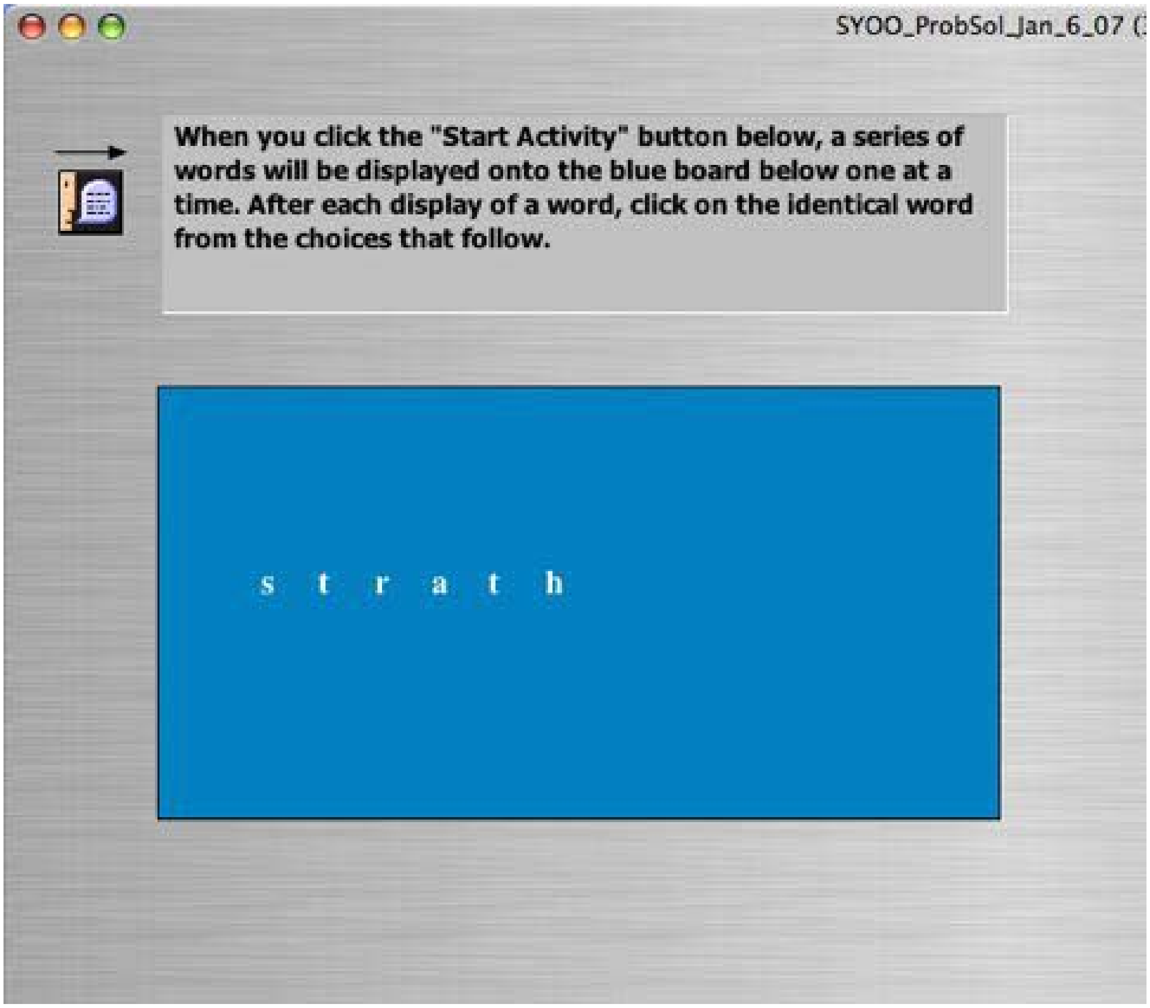
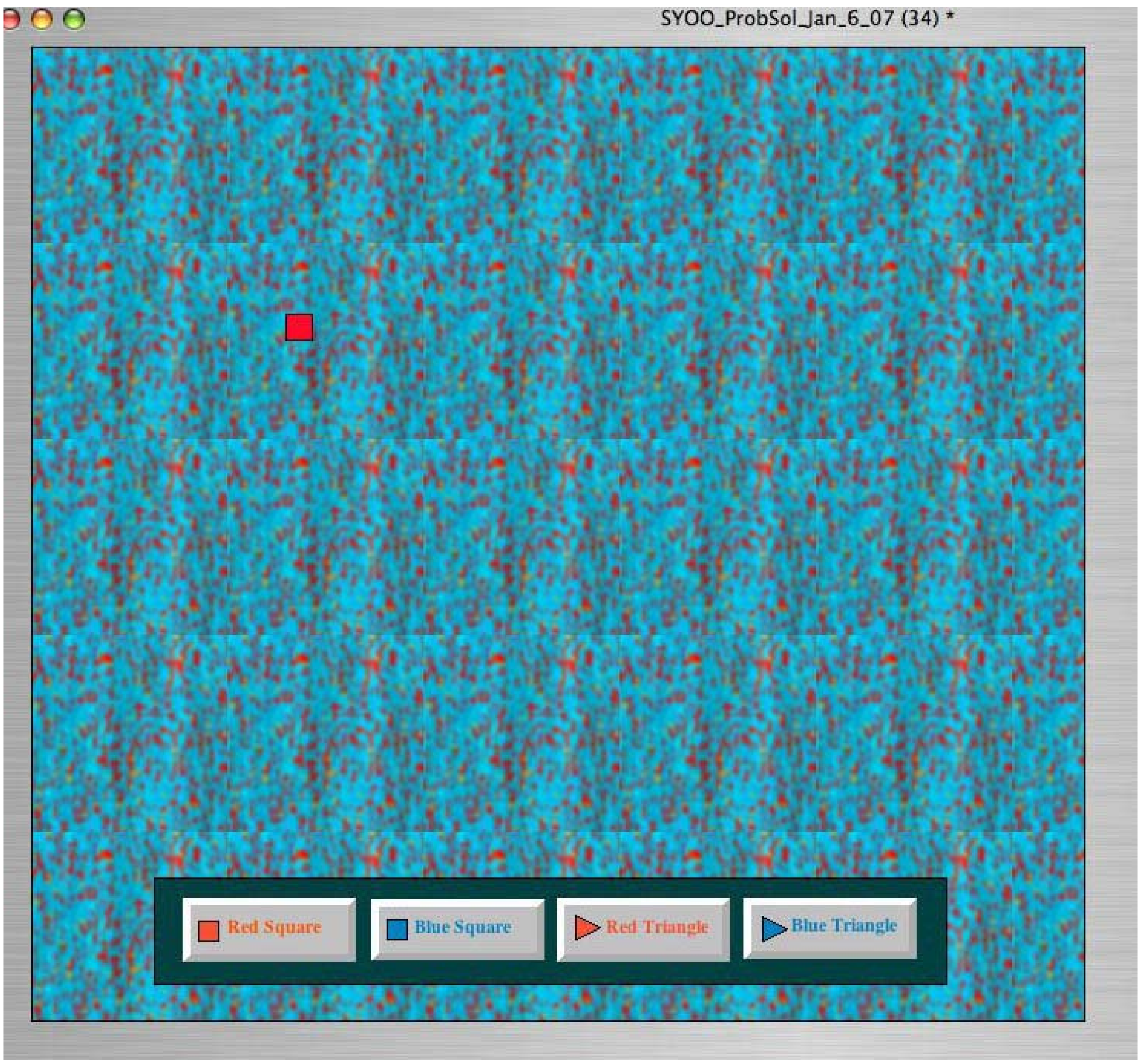


FIGURE 19. Interface for the Verbal Interruption Task group. Upon seeing letter stimuli, the subjects were asked to identify the word that the letters formed by clicking over one from the subsequent three word choices.



Spatial Interruption Task. The Spatial Interruption Task group interacted with geometric stimuli that changed at intervals of two seconds; the stimuli varied randomly in color, red and blue, and two shapes, triangle and square (i.e., a red triangle, red square, blue triangle, or blue square). Each of the stimuli flashed for one second at a random location against a somewhat visually complex screen background. Upon seeing a stimulus on the screen, the subjects were supposed to immediately respond to it by clicking on the designated button; for example, when a problem solver saw a red triangle flashing somewhere on the screen, the problem solver was expected to press the button labeled ‘Red Triangle’. See Figure 20 for the interface of this activity.

FIGURE 20. The Spatial Interruption task. Each of the stimuli, varied in color and shape, showed up in random locations against a somewhat disturbing background and disappeared in one second. Upon seeing it, subjects identified its shape and color by clicking one of the buttons located at the bottom of the screen.



Data Recording

Participants' interactions with the problem content were monitored and recorded by the computer. When the participants moved a problem component on the screen, or pressed a button to select an option or submit their work, the response time and button names were saved along with their responses. The interruption activity data were similarly recorded. While the participants were interacting with the verbal or spatial stimuli, reaction time, total response counts and correct reactions were recorded. When the time allowed for each problem session or interruption task session reached, the interaction data were also saved as an external data file.

Scoring

Data from 185 participants were analyzed. Participants' performance was scored on both correctness and time spent. Correct responses on each item were scored 1, and incorrect responses were scored 0. Thus, the highest individual score was 3 points. The time spent was computed by summing up the time in seconds that a participant took while interacting with the three problems; this total did not include time spent reading the problem instructions.

Results

Analysis 1: Spatial Problems

Data from 98 undergraduate students who interacted with the spatial type of problems were used for this analysis. The spatial problems consisted of two coin arrangement problems and one chain connection problem. A descriptive analysis of the participants' performance on each session of problem solving (as summarized in Table 4) indicated that in the initial problem solving session, the No-Interruption Task and

TABLE 4. Means and Standard Deviations on Spatial Problems.

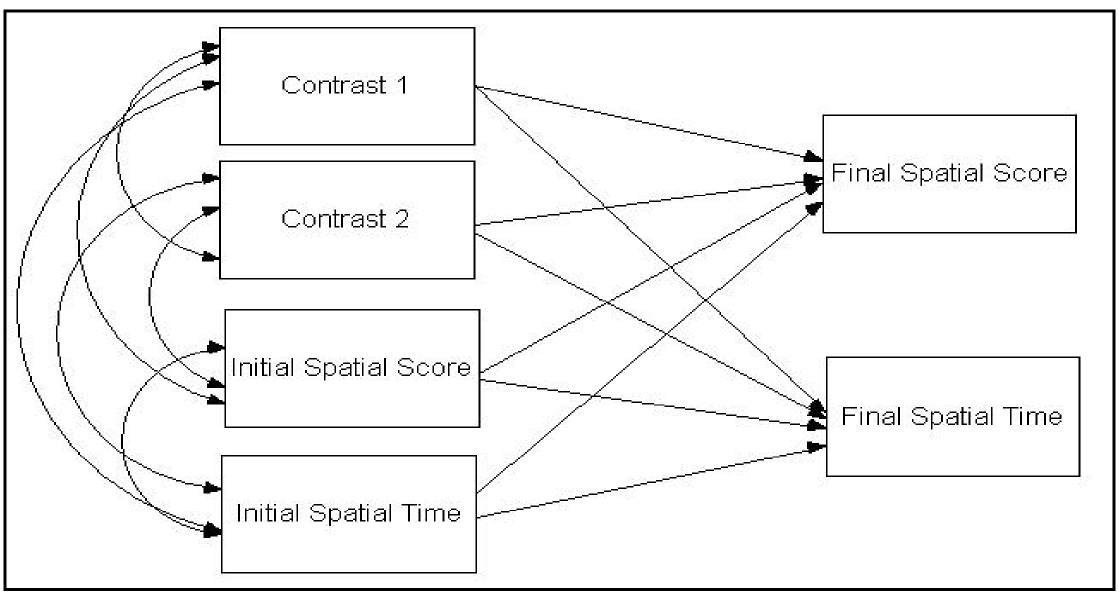
		[a] Score (Max 3pts)		[b] Time (Max 420 sec)	
Group		Initial	Final	Initial	Final
No Interruption (Control) n = 32	Mean	0.91	1.28	287.18	300.33
	SD	0.82	0.58	60.14	81.86
Verbal Interruption Task n = 33	Mean	0.91	1.24	284.98	255.12
	SD	0.72	0.90	76.15	105.89
Spatial Interruption Task n = 33	Mean	0.85	1.36	268.67	233.76
	SD	0.87	0.90	68.90	90.63
Total N = 98	Mean	0.89	1.30	280.20	262.69
	SD	0.80	0.80	68.58	96.55

[a] Sum of the item scores. Each item was dichotomously scaled: right = 1 and wrong = 0.
[b] Sum of the seconds that an individual spent while interacting with the problems. This score does not include time spent reading the problem instructions.

Verbal Interruption Task groups scored slightly higher than the Spatial Interruption Task group in terms of the mean score: No-Interruption Task = 0.91, Verbal Interruption Task

= 0.91, and Spatial Interruption Task = 0.85. On the other hand, on the final problem solving session, the Spatial Interruption Task group performed slightly better than the other groups: No-Interruption Task = 1.28, Verbal Interruption Task = 1.24, and Spatial Interruption Task = 1.36.

FIGURE 21. Regression model for the spatial problems (anagrams). Contrast 1 compares No-Interruption Task (the coefficient: 2) with two Interruption Tasks (the coefficient for each group: -1). Contrast 2 compares two Interruption Tasks (coefficients: the Verbal Interruption Task = -1, Spatial Interruption Task = 1, and No-Interruption Task = 0). The double headed arrow between variables indicates that they are correlated.



To compare the groups' performances, a regression analysis was conducted. Since individual score range was limited between 0 to 3, MLM, an estimator known to be robust to normality violation (Muthén & Muthén, 2004) was used. The final session score and time were the criterion variables. The initial session score, initial session time, and two contrasts (Contrast 1 and Contrast 2) were included as covariates. The two contrasts of groups were made to determine 1) if the Interruption Task groups together performed differently from the No-Interruption Task (Control) group and 2) if the two Interruption Task groups performed differently from each other. There was not a statistically significant group difference either on the initial session score, $F(2, 95) = 0.06$, $p = .94$ or on the final session time, $F(2, 95) = 0.71$, $p = .50$. The model used in this study was detailed in Figure 21 (CFI =1.0, SRMR =0.01).

Correlation coefficients between variables were summarized in Table 5. The initial session score was positively correlated with the final session score ($r = .5$). The relationship between the initial problem solving score and the initial problem solving time was negative ($r = -.3$). This indicated that during the initial problem solving session the subjects who spent more time were less successful in finding the solution. However, no relationship was determined between the initial session time spent and the final session score ($r = -.1$), or between the initial and final session time spent ($r = .1$). Contrast 1 and 2 were associated with the final session time spent at the minimal level ($r = .2$ and $.3$, respectively).

TABLE 5. Correlation of Variables on Spatial Problems.

	1	2	3	4	5	6
1. Final Spatial Score	__	-.04	.52	-.13	-.06	-.01
2. Final Spatial Time		__	-.08	.12	.21	.27
3. Initial Spatial Score			__	-.30	.05	.02
4. Initial Spatial Time				__	-.04	.07
5. [a] Contrast 1					__	.07
6. [b] Contrast 2						__

[a] Comparison between No-Interruption Task and two Interruption Task groups.
[b] Comparison between Spatial Interruption Task and Verbal Interruption Task.

As shown in Table 6, the results from the regression analysis indicated that the initial session score was an important predictor for the final session score and the initial session time, but the initial time was not. Contrast 1 and 2 were associated significantly with the final session time but not with the final session score. This meant that in terms of response scores, there was no difference between the Interruption Task groups and the control group or between the two Interruption Task groups.

On the other hand, the combined Interruption Task groups and the control group (Contrast 1) differed in terms of their time spent from the initial to the final problem solving. The standardized regression coefficient of Contrast 1 on the time used was 0.22 ($t = 2.40$, $p < .05$). This result explained that the No-Interruption Task group spent significantly more time than the Interruption Task groups. Put another way, the time use of the participants in the Interruption Tasks groups were more reduced than that of those in the Control group.

Based on the Contrast 2, the performance of the two Interruption Task groups did not differ on score but did differ on time significantly. The results indicated that given the initial problem solving score as a covariate, the Spatial Interruption Task group spent less time than the Verbal Interruption Task group on the final problem solving. The experimental groups' mean time differences from the initial to the final problem solving are shown in Table 7. During the final problem solving session, the No-Interruption Task group spent an average of 13.2 more seconds than on the initial problem solving. On the other hand, the Interruption Task groups together spent an average of 32.4 less seconds during the final problem solving session than during the initial problem solving session. The Spatial Interruption Task group manifested the greatest decrease of time spent.

TABLE 6. Regression Estimates on the Final Spatial Performance Score and Time.

	B	S.E.	t.	ß
Criterion: Final Session Score				
Contrast 1	-0.25	0.24	-1.02	-0.09
Contrast 2	-0.01	0.05	-0.22	-0.02
Initial Session Score	0.54	0.09	**5.79	**0.53
Initial Session Time	0.01	0.01	0.35	0.03
Criterion: Final Session Time				
Contrast 1	75.44	31.40	*2.40	*0.22
Contrast 2	17.21	6.22	**2.77	**0.25
Initial Session Score	-7.95	12.60	-0.63	-0.06
Initial Session Time	0.13	0.14	0.96	0.09

Note. $R^2 = 0.28$ on the final problem solving score, $R^2 = 0.13$ on the final problem solving time.
*$p < .05$. ** $p < .01$.

The different time uses of the groups were more obvious when they were compared in terms of the reduced time spent from the initial problem solving to the final problem solving. It was shown that the participants in the Interruption Task groups spent much less time than those in the No-Interruption group. Between the two Interruption Task groups, the Spatial Interruption Task group showed greater time decrease than the Verbal Interruption Task group from the initial problem solving to the final problem solving. Interestingly, while the No-Interruption Task group spent more time during the final problem solving session than during the initial problem solving session, the Interruption Tasks groups spent much less time during the final problem solving session than during the initial problem solving session.

TABLE 7. Mean Differences of Time Spent from the Initial to the Final Session by Group on Spatial Problems.

Interruption Task	Initial Mean (sec)	Final Mean (sec)	Mean Differences (sec)
None (n=32)	287.18	300.33	13.15
Verbal (n=33)	284.98	255.12	-29.86
Spatial (n=33)	268.67	233.76	-34.91
Verbal & Spatial (n= 66)	276.83	244.44	-32.39

Analysis 2: Verbal Problems (Anagrams)

This analysis included data from 87 undergraduate students who worked on the verbal problems (anagrams). The same method used with the spatial problems was also applied to this analysis. The general performances of the groups were summarized in

TABLE 8. Means and Standard Deviations on Verbal Problems.

		[a]Score (Max 3pts)		[b]Time (Max 300 sec)	
Group		Initial	Final	Initial	Final
No-Interruption Task (Control) n=29	Mean	0.90	1.21	246.77	191.16
	SD	0.72	0.86	49.28	81.81
Verbal Interruption Task n=29	Mean	0.59	0.90	250.14	188.66
	SD	0.50	0.82	49.64	87.79
Spatial Interruption Task n=29	Mean	0.83	1.03	255.92	162.31
	SD	0.76	0.91	50.12	92.35
Total n=87	Mean	0.77	1.05	250.94	180.71
	SD	0.68	0.86	49.24	87.39

[a] Sum of the item scores on the anagram problems.

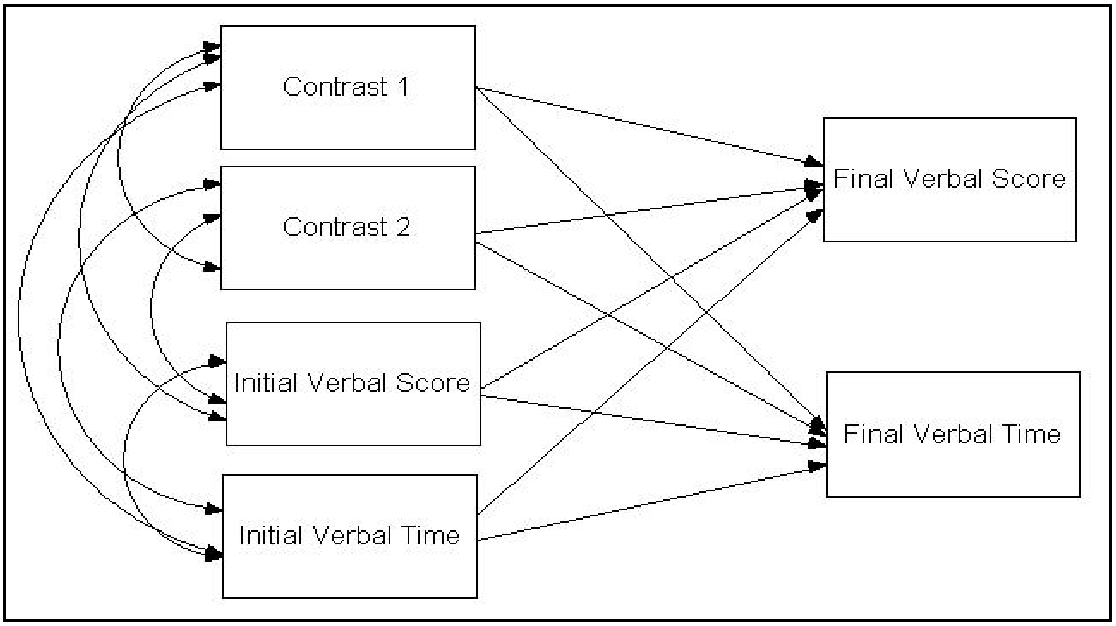
[b] Sum of the seconds that an individual spent while interacting with the problems.

During the initial problem solving session, the mean scores of the No-Interruption Task and Spatial Interruption Task groups were slightly higher than that of the Verbal

Interruption Task group: No-Interruption Task = 0.90, Verbal Interruption Task = 0.59, and Spatial Interruption Task = 0.83. There was not a statistically significant group difference either on the initial problem solving score, $F(2, 84) = 1.71$, $p = .19$, or on the final problem solving time, $F(2, 95) = 0.25$, $p = .78$. In the final problem session, the No-Interruption Task and Spatial Interruption Task groups scored slightly higher than the Verbal Interruption Task group as well: No-Interruption Task = 1.21, Verbal Interruption Task = 0.90, and Spatial Interruption Task = 1.03. See Table 8 for details.

In order to determine how the groups' performance had been changed from the initial to the final problem solving, a regression analysis was applied. The initial problem solving score, initial problem solving time, and two contrasts (Contrast 1 and Contrast 2) were entered as covariates and the final problem solving score and final problem solving time were treated as the criterion variables. Contrast 1 compared the No-Interruption Task group with the two Interruption Task groups. Contrast 2 compared the two Interruption Tasks groups. The model used for this analysis was shown in Figure 22 (CFI=0.98, SRMR=0.03).

FIGURE 22. Regression model for the verbal problems (anagrams).
Contrast 1 compares No-Interruption (the coefficient: 2) with two Interruption Tasks (the coefficient for each group: -1). Contrast 2 compares two Interruption Tasks (coefficients: the Verbal Interruption Task = -1, Interruption Task Spatial = 1, and No-Interruption Task = 0). The double headed arrow between variables indicates that they are correlated.



The correlation matrix of the variables showed the positive relationship between the initial and the final session scores (r = .72) and between the initial and the final problem solving time (r=.34). On the other hand, the initial problem solving time was negatively related with both the initial problem solving score(r = -.30) and the final session score (r = -.30). See Table 9 for details. This result indicated that the participants who spent relatively more time in the initial session were less likely to find the solutions to the anagrams in the final session. This result was comparable to the finding from the previous analysis with the spatial problems where the time spent for the initial problem solving was not correlated with the scores on the final problem solving.

TABLE 9. Correlation of Variables on Verbal Problems.

	1	2	3	4	5	6
1. Final Verbal Score	__	.02	.72	-.30	.12	.13
2. Final Verbal Time		__	-.24	.34	-.14	.09
3. Initial Verbal Score			__	-.30	.17	.13
4. Initial Verbal Time				__	-.09	-.06
5. [a] Contrast 1					__	.04
6. [b] Contrast 2						__

a: Compared the No-Interruption Task group with the combined Interruption Task groups.

b: Compared the two Interruption Task groups (Incubation-Task Verbal and Incubation-Task Spatial).

When the final session score and the final session time were regressed on the predictor variables using the MLM method, it was identified that the initial problem solving score and the initial problem solving time were both significant indictors for the final problem solving performance. This result contradicted the prior findings on the spatial problems where the initial problem solving time was not a significant predictor. Neither Contrast 1 nor Contrast 2 returned a significant group effect on the final session performance. See Table 10 for details.

TABLE 10. Regression Estimates on the Final Verbal Performance Score and Time.

	B	S.E.	t	ß
Criterion: Final Session Score				
Contrast1	0.16	0.25	0.67	0.05
Contrast 2	0.01	0.04	0.18	0.01
Initial Session Score	0.96	0.10	**10.04	**0.76
Initial Session Time	0.01	0.01	**3.21	**0.21
Criterion: Final Session Time				
Contrast 1	-31.38	28.04	-1.12	-0.10
Contrast 2	7.86	6.06	1.30	0.13
Initial Session Score	-20.61	12.01	-1.72	-0.16
Initial Session Time	0.52	0.22	*2.38	*0.29

Note. R2 = 0.56 on the final session score, R2 = 0.16 on final session time.
p < .05. ** *p* < .01.

Although the effect sizes of the contrasts (Contrast 1: -1.12; Contrast 2: 1.30) on the final problem solving performance time did not reach the significant level, they indicated a small size of impact of the Interruption Tasks on time. Contrast 1 manifested that the relationship between the initial and the final problem solving performance of the subjects in the Interruption Task groups was greater than the relationship between the initial and final problem solving performance of the subjects in the No-Interruption Task group. The regression coefficient for the Spatial Interruption Task group was slightly greater than that for the Verbal Incubation Task group. These findings on time spent were consistent with the results from the prior analysis with the spatial problems. The trend in the time use of the groups was more obvious when comparing the groups in terms of the decreased time spent from the initial to the final problem solving session (see Table 11). The Interruption Tasks group together spent less time than the No-Interruption Task group, and the Spatial Interruption Task group took less time to solve the problems than the Verbal Interruption Task group. Although the effect size of the combined Interruption Task group did not reach the significant level, the time difference determined between the Interruption Task groups and the No-Interruption Task group implied the positive impact of the Interruption Tasks on the participants' final problem solving performance.

TABLE 11. Mean Differences of Time Spent from the Initial to the Final Session by Group on Verbal Problems.

Interruption Task	Initial Mean (sec)	Final Mean (sec)	Mean Differences (sec)
No-Task (n = 29)	246.77	191.16	-55.61
Verbal (n = 29)	250.14	188.66	-61.48
Spatial (n = 29)	255.92	162.31	-93.61
Verbal & Spatial (n = 58)	253.03	175.49	-77.55

Note. Negative numbers indicate the amount of time reduced from the initial to the final problem solving.

Based on the findings from the participants' performance on each of the two different types of problems, the second research question, "Is there interaction between the two types of insight problems, verbal and spatial, and the two types of Interruption

Tasks, verbal and spatial?" was answered. Interaction between the two types of problems and Interruption Tasks could not be evidenced from this study. The Interruption Tasks appeared to influence significantly only the performance of the subjects who were working on the spatial problems. There was no significant effect of the Interruption Tasks on the performance of those who were working on the verbal problems (anagrams). Additionally, the similar pattern in the time spent to complete the problems by the two Interruption Task groups between the two types of problems also showed no interaction of the problems and Interruption Tasks. The results implied that the spatial Interruption Task might be more effective to influence the subjects, than did the verbal Interruption Task, for both spatial and verbal problems (anagrams).

Discussion

The experiments were conducted to examine the effects of the intervening tasks on resolving two types of insight problems, spatial and verbal (anagrams), and to explore the potential problem interaction between problem type and interruption task type.

Incubation Effects

The first research question was *Do the two interruption task Groups, combined and individually, perform differently on the final problem solving tasks from the No-Interruption Task group (or Continuous Working group) on each type of insight problem?* . To answer this question, incubation effects were operationally defined as the greater performance of the interruption task groups than the control on problem solving performance score (higher score). On the spatial problems, the performance of the

Interruption Task groups combined was not different from that of the No-Interruption Task group in terms of response accuracy. However, the time spent for the interruption task group combined was different from that of the No-Interruption Task group. This indicated that the Interruption Task groups spent much less time than the No-Interruption Task group.

This finding might also indicate the participants who were working on the second trial of spatial problems could figure out the solutions to the problems more quickly when they were distracted by an Interruption Task than those who did not have an interruption task. This assertion was supported by the result from comparing only those members of each group who were not successful during the initial session but finally figured out the solution during the final session (resolvers), specifically on the spatial problem 1 and 2. The performance on the third problem was not taken into account because of its much lower resolution rate than the other preceding problems.

As seen in Table 12, when comparing only the performance of those who resolved the problems during the final session, the result indicated that the resolution rates were similar among the groups. However, both the interruption task groups spent less time than the control group. The Spatial Interruption group spent the least time among the groups. These findings were consistent with the previous analyses of the performances of the groups. Therefore, these results implied that given the similar resolution rates across the groups, the participants who were working on the second trial of spatial problems came to the solutions to the problems more quickly when they were distracted by an Interruption Task. This result, thus, partially supported the interpretation that the interrupting task enhances problem solving performance.

TABLE 12. Time Use and Resolution Rate by Group on Spatial Problem 1 and 2.

Group	[a] Time	[b] Number of Resolution Cases	[c] Resolution Rate
Control	164.10	15	42%
Verbal Interruption	153.06	14	38%
Spatial Interruption	143.78	16	40%

[a] The amount of time spent solving problem 1 and 2 of the spatial problems during the final session.
[b] The number of the cases that an unsolved problem in the initial session was solved during the final session. This number was calculated by combining the cases for each of the Spatial problem 1 and Spatial problem 2.
[c] The percentage of the resolution cases in relation to the total cases unsolved during the initial session.

On the verbal problems (anagrams) the interruption task group combined did not show a significant performance difference from the control group in response accuracy. The response time of the interruption task group combined spent slightly less time, although not reaching the significant level, than the control group. When the two interruption task groups were compared in terms of the time spent to complete the problems, it was identified that the Spatial Interruption Task group used slightly less time than the Verbal Interruption Task group for both types of problems.

The observed difference in performance related to the types of problems may be due to the different processes required for the two types of problems. The solutions to the spatial problems all require the transformation of an original arrangement to another. Thus, perceptual restructuring of the patterns could be a key process for the solutions to the problems. According to Bowden (1997), restructure of the problem representation is the crucial property of insight. In contrast, the processes involved in working with the verbal problems (anagrams) are generally regarded as including both the forward thinking process and illumination (Finke, Ward, & Smith, 1992). Thus, working with the spatial problems might be more associated with the insightful process than working with the verbal problems (anagrams). Put another way, this result may imply that problems requiring an insightful solution may benefit more from an incubation activity. Future research should further examine the relationship between insight and incubation effects including the incorporation of more diverse types of problems.

Alternatively, this performance gap between the two types of problems may be attributable to subjects' unequal level of learning from the initial to the final session between the two types of problems. When attempting the second problems solving session, people may be more likely to remember their first session on the verbal types of problems, than on the spatial types of problems. For example, the problem solver is more likely to forget the complex solution sequence he/she took to solve a coin rearrangement problem in the initial session; in contrast, he/she is less likely to forget the final word(s) that he/she spelled previously with the letter stimuli in an anagram problem. The high consistency from the subjects' initial to the final problem solving performances shown on the verbal problems (anagrams) may support this interpretation. Thus, future studies may include different sets of problems for the final session in order to control the potential differential effects of remembering of the initial problem solving activities.

No Interaction between Problems and Interruption Tasks

The second research question was *Is there interaction between the two types of insight problems (verbal and spatial), and two types of interruption tasks?* . The analyses results indicated that the Spatial Interruption Task group outperformed the Verbal Interruption Task group in terms of the time decrease from the initial to the final performance for both types of problems. The incubation effects on time spent were significant for solving the spatial problems but not for the verbal problems (anagrams). Thus, these findings did not show interaction between the problem types and Interruption Task types.

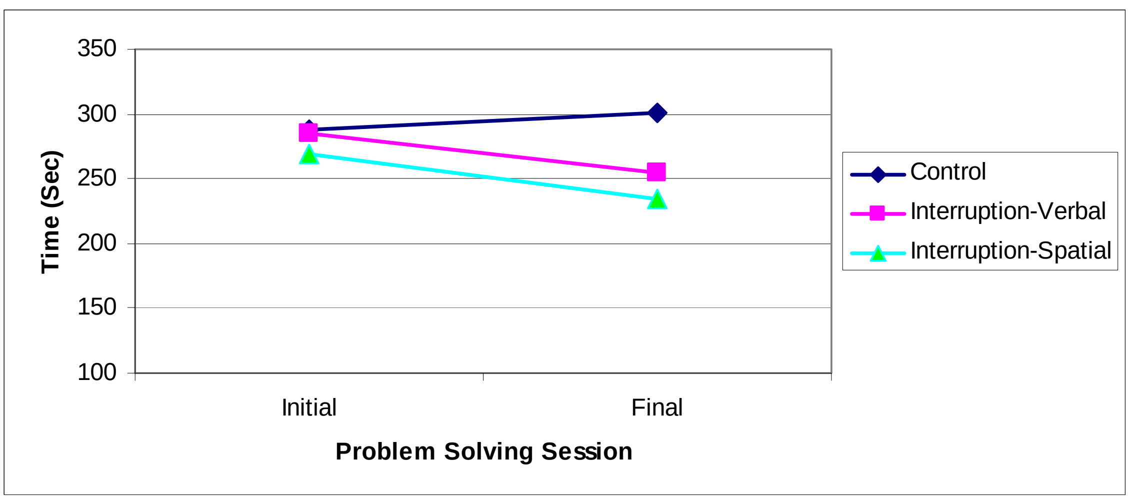
A possible account for this finding would be the different levels of cognitive demands between the two types of incubation activities. When interacting with the spatial task, subjects might be more attentive to the stimuli because they changed in multiple facets of properties: the spatial task stimuli changed in shape, color and location for each display. In contrast, letters of the verbal task stimuli were presented at a very similar location without changing of the color for each display. Smith & Blankenship (1989, 1991), in their fixation-forgetting approach, suggested that attention is a crucial factor in solving a problem. Retreating from focused attention to a problem by engaging in an interruption task can enhance problem solving. Interacting with an interruption task can help a problem solver forget an inappropriate approach previously applied and then increase the possibility to find a solution to an unsolved problem.

Consequently, it is possible that subjects paid more attention to the stimuli in the spatial interruption task, and this helped them forget about the approaches they applied to the problems in the initial session. This could lead them to quicker solutions to the problems in their final problem solving task.

Time Use Patterns and Insight

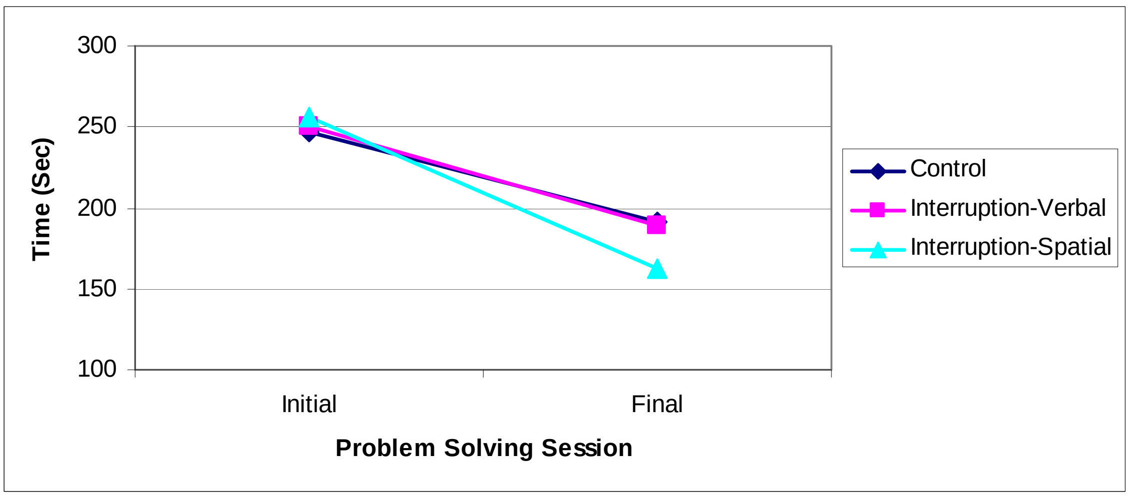
The different performance pattern across the groups on the different types of problems was identified by the average time spent during the problem solving sessions. On the spatial problems, the control group spent more time during the final problem solving session than during the initial session. However, the participants who engaged in

FIGURE 23. Average time spent by the groups during the initial and final problem solving sessions on the spatial problems.



an interruption task spent much less time during the final problem solving session than during the initial session (See Figure 23). On the contrary, on the verbal problems (anagrams), all participants from both the interruption task and control groups spent much less time in the final session than in the initial session (See Figure 24).

FIGURE 24. Average time spent by the groups during the initial and final problem solving sessions on verbal problems (anagrams).



This result was possibly because that the subjects could remember more about the correct answers and attempts in the verbal problems (anagrams) than in the spatial problems. Consequently, the subjects spent much less time in the final session than in the initial session on the verbal problems. This finding may also support the idea that the cognitive processes required for solving the spatial problems may be distinguished from those required for the verbal problems (anagrams); i.e., the processes required in solving the spatial problems are more likely to involve insight. Considering that the accuracy score results were not different between the control and the interruption task groups, the less time use of the incubation task groups meant that the subjects in the incubation task groups were quicker than others in solving the same number of problem items. Consequently, the interruption task groups' lower time use in the second problem solving session, as compared to the control group, may indicate that participants become more insightful from working with the spatial problems. Conversely, this may imply that an interruption task was more beneficial when the problem tasks require a more insightful process.

Conclusion

Summary

The current study explored incubation effects in problem solving involving more than one type of interruption task. Further, the study examined the potential interaction between the types of problems and types of interruption tasks included in this study. Two types of problems were the spatial (pattern change) and verbal (anagram) problems, and two types of interruption tasks were the spatial stimuli reaction and verbal stimuli reaction tasks.

The findings from the present study partially support the contention that problem solvers can benefit from an interruption task when finding solutions to insight problems. Thus, it is suggested that a problem solver can resolve the problem more quickly when temporarily interrupted by a simple cognitive task. Additionally, the study results implied that a problem solver could benefit from an interruption task that involves stimuli changing in attributes and location. The subjects in this study were faster in solving problems provided with stimuli changing in attributes and location than they were given with stimuli without such changes.

Although the present study did not find any effects of interaction between the problem types and interruption tasks included, the findings provided some insight into the type of intervening tasks that would promote insight problem solving. Given spatial-pattern problems, an intervening task which involved stimuli varying in multiple facets of properties (e.g., different colors, shapes and locations) was suggested to be more effectual than stimuli varying in only one dimension (e.g. different text). This may be because the stimuli involving multi-dimensional change are more likely to enhance subjects' global attention to the problems at hand. Importantly a task involving both the spatial and visual processes might promote shifting from focused attention to more global attention. The majority of the existing studies on incubation have employed an incubation task with only single modality. Future research should be focused on the effects of multi-modal vs. singular-modal stimuli interruption on problem solving.

Recommendations for Future Research

In this study incubation effects were evidenced in terms of time but not in terms of accurate response rates. Only the spatial interruption task had a positive impact on solving the spatial problems. This may be because the time assigned to the problem solving sessions and/or the time allocated to the interruption tasks was not appropriately established. In the current study the control groups spent less total experimental time (by 5 minutes) than the interruption task groups because they did not have an interruption session. Therefore, it was possible that this disparity in the amount of time spent among the groups impacted the findings in some ways. For instance, the subjects in the interruption task groups might become tired after interacting with the interruption activities making them want to finish the second problem solving session quickly. Future studies may consider including a non-work experimental condition for each type of problem in order to control the possible effect caused by the difference in the amount of time spent among the groups.

In addition, this study allocated a little longer time to the spatial problems than to the verbal (anagram) problems (seven minutes for the spatial problems vs. five minutes for the verbal problems). Thus, it was possible that the gap in the amount of time spent by the subjects impacted the study results. Future studies my consider allocating the same amount of time to the different types of problems.

The current study used the same set of problems for both initial and final problem solving sessions. Thus, the subjects saw the same problems during the both sessions. It was possible, especially more true on the verbal types of problems, that during the final session the subjects remembered how they responded to some of the problems they saw during the initial problem solving session. This practice effect might compound the study results, further making it difficult to examine the potential interaction pattern between problem types and incubation task types if the degree of the practice effects was not identical between the two problem types. In later studies this problem can be solved employing a different set of, but the same type of, problems during the final problems session.

It is also notable that the majority of the participants were majoring in education. Therefore, the results could be better applicable to the education majors. Future studies need to include more subjects from diverse majors and backgrounds.

Finally, a few technical problems, although minor, were identified during the experiment. These problems possibly impeded some participants from fully demonstrating their problem solving ability. Based on the researcher's observation, there were one or two cases where some of the components of the coin puzzle problems did not worked smoothly. On a survey question integrated into the computerized assessment, a few students pointed out that the objects in the chain linking question were not moved smoothly as they desired. Such technical features need to be addressed for later studies.

CHAPTER IV

CONCLUSION

This study employed a computer-based research management technique to examine the effects of interruption tasks and potential effects of interaction between problem types and interruption task types on problem solving. The computer-based approach was presented as having advantages over the conventional assessment formats such as the following: (1) it provided subjects with dynamic interfaces that simulate real world problem operations, and (2) it allowed all performance data to be internally saved and managed in relation to group placement, sequence of activities, activity type, etc., and consequently, it made it possible for the researchers to collect detailed information about subjects' responses, response time, interaction sequences, trial accounts, demographic information, and perception. It was suggested that data collected using such computerized programs would help illuminate the role of incubation and other cognitive phenomena associated with problem solving.

The performance data from the two problem solving sessions were analyzed using the regression analysis method. The findings indicated that problem solvers resolved problems more quickly when distracted by a simple cognitive task than when continuing the original problems uninterrupted. The study results also implied that problem solvers benefit more from an interruption task involving stimuli having both visual and spatial components.

Although the present study could not find any effects of interaction between the problem types and interruption task types, the findings provided insight into the type of intervening tasks that would promote successful problem solving. An intervening task which involved monitoring the intermittent appearance of stimuli varying in multiple facets of properties (e.g., different colors, shapes and locations) was suggested to be more effectual than that with stimuli varying in only one dimension (e.g. different words). This may be because the stimuli involving multi-dimensional change are more likely to enhance subjects' global attention to the problems at hand. Thus, it was concluded that an interruption task would be more effective for problem solving when its attention level is optimally established. Future studies need to examine more closely how the incubation phenomena is associated with global attention.

Finally, a few recommendations were made for future studies. Incubation effects were evidenced in terms of time but not in terms of accurate response rates. Only the spatial interruption task had a positive impact on solving the spatial problems. This may be because the time assigned to the problem solving sessions and/or the time allocated to the interruption tasks was not appropriately established. In the current study the control groups spent less time (by 5 minutes) than the interruption task groups because they did not have an interruption session. Therefore, it was possible that this disparity in the amount of time spent among the groups impacted the findings in some ways. For instance, the subjects in the interruption task groups might become tired after interacting with the interruption activities making them want to finish the second problem solving session quickly. Future studies may consider including a non-work experimental condition for each type of problem in order to control the possible effect caused by the difference in the amount of time spent among the groups.

In addition, this study allocated a little longer time to the spatial problems than to the verbal problems (seven minutes for the spatial problems vs. five minutes for the verbal problems). Thus, it was possible that the gap in the amount of time spent by the subjects impacted the study results. Future studies my consider allocating the same amount of time to the different types of problems.

The current study used the same set of problems for both initial and final problem solving sessions. Thus, the subjects saw the same problems during the both sessions. It was possible, especially more true on the verbal types of problems, that during the final session the subjects remembered how they responded to some of the problems they saw during the initial problem solving session. This practice effect might compound the study results. In later studies this problem can be solved employing a different set of, but the same type of, problems during the final problems session.

Also notably, the majority of the participants were majoring in education. Therefore, the results could be better applicable to the education majors. Future studies need to include more subjects from diverse majors and backgrounds.

Finally, a few technical problems, although minor, were identified during the experiment. These problems possibly impeded some participants from fully demonstrating their problem solving ability. Based on the researcher’s observation, there were one or two cases where some of the components of the coin puzzle problems did not worked smoothly. On a survey question integrated into the computerized assessment, a few students pointed out that the objects in the chain linking question were not moved smoothly as they desired. Two participants indicated the spatial Interruption Task made their eyes tired. The computer-based technique should be modified for future use.

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APPENDIX A

Additional Review of Incubation Research

A few studies attempted to demonstrate the effect of an incubation period. Patrick (1938) asked subjects to propose scientific methods to investigate effects of heredity and the environment on humans and reported that the experimental groups who had the incubation period received high scores than the control group who continuously worked without the break. More recently, Olton (1979) presented a challenging chess problem to subjects. Control subjects worked continuously whereas subjects in the incubation group were instructed to take a two-hour break sometime during their work. Olton reported no evidence of incubation with this study. Kaplan (1989) used “Consequences” problems and found the incubation group who took a 30-minute break superior to the control group on fluency (the number of ideas generated). The items of “Consequences” require subjects to generate consequences to questions such as, "What would happen if everyone suddenly lost the ability to read and write?" (cited by Dodds et al., 2004).

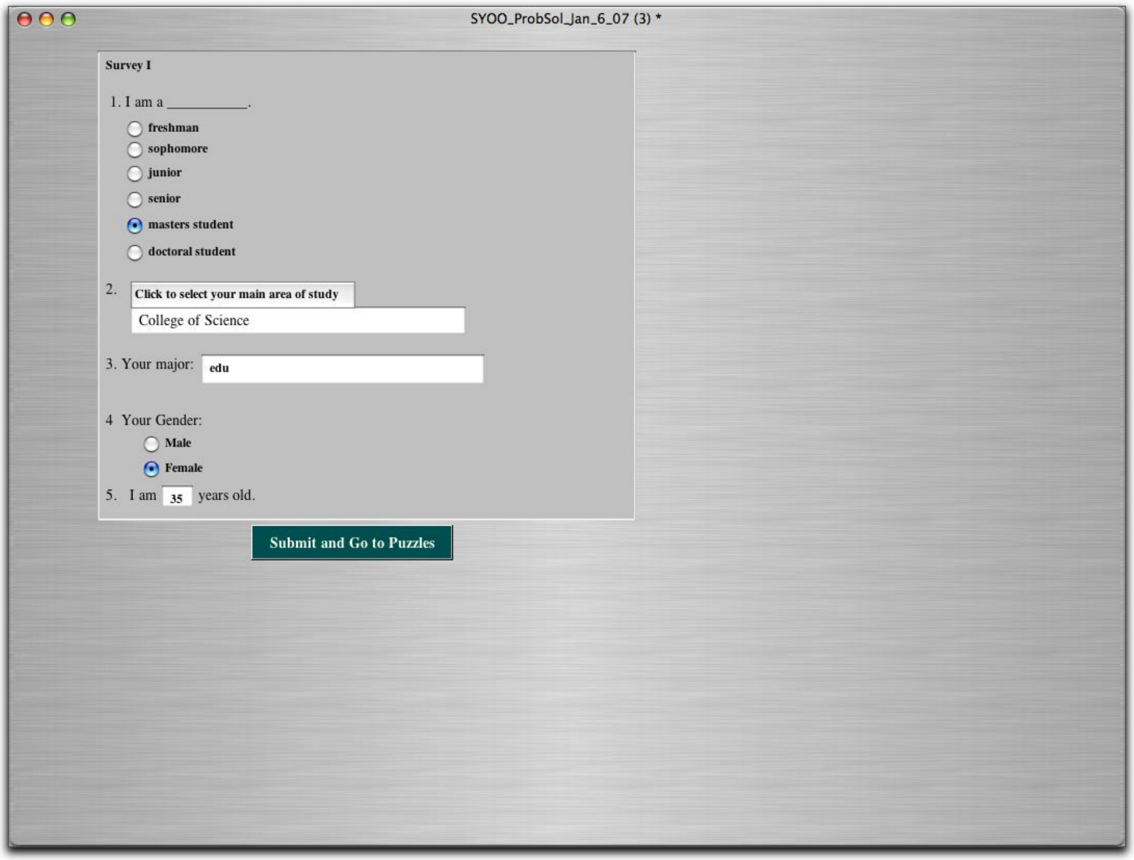
Some studies were focused on the initial activities before incubation. Silveira (1971) was interested in the duration of the initial activities before incubation using the chain problem. In the problem, a man with four chains of three links each wants the chains joined into a single, closed circle. Having a link opened costs $.02 and having a link closed costs $.03. The subjects are asked to how the man had the chains joined in a closed circle for only $.15. The author determined a significant effect of the timing of interruption; those interrupted later in the session were more likely to resolve the problem than those interrupted earlier.

Some other studies were interested in the duration of the incubation period. For example, Fulgosi & Guilford (1968) measured the participants' answers on fluency (a total number of ideas generated) and originality (how remote the ideas from the norm). They concluded the incubation effect was likely to be maximized with 20 to 30 minutes' incubation break. Smith and Blankenship (1989) also manipulated the length of time in the incubation period during their experiments with rebus word puzzles, in which words are arranged to create pictures. In their second experiment, it was revealed that subjects in the 15-minute interruption group performed better than those in either the 5-minute interruption or control groups.

A few studies were focused on the effects of clues provided during the incubation period or with problems. Driestadt (1969) was concerned with how visual clues (analogies) to problem solutions introduced during incubation period would influence subjects' final performance. Using insight problems, they found strong effects of being exposed to the pictorial clues. Olton and Johnson (1976), however, in replicating Driestadt' study, could not determine the analogy effects in problem solving. Smith and Blankenship (1989, 1991) used misleading clues in order to examine the effects of misleading clues (clues leading to a wrong track) on incubation. They found subjects who were misled by the clues were more likely to benefit the incubation period for resolving the problems. Similarly Vul and Pashler (2007) found that only those subjects who were provided with misled clues showed incubation effects. In their experiments they tested effects of five-minute video game during the incubation period on each of the anagrams and remote associate test problems, either with or without misleading clues. They found incubation effects only with the misled (fixation) group.

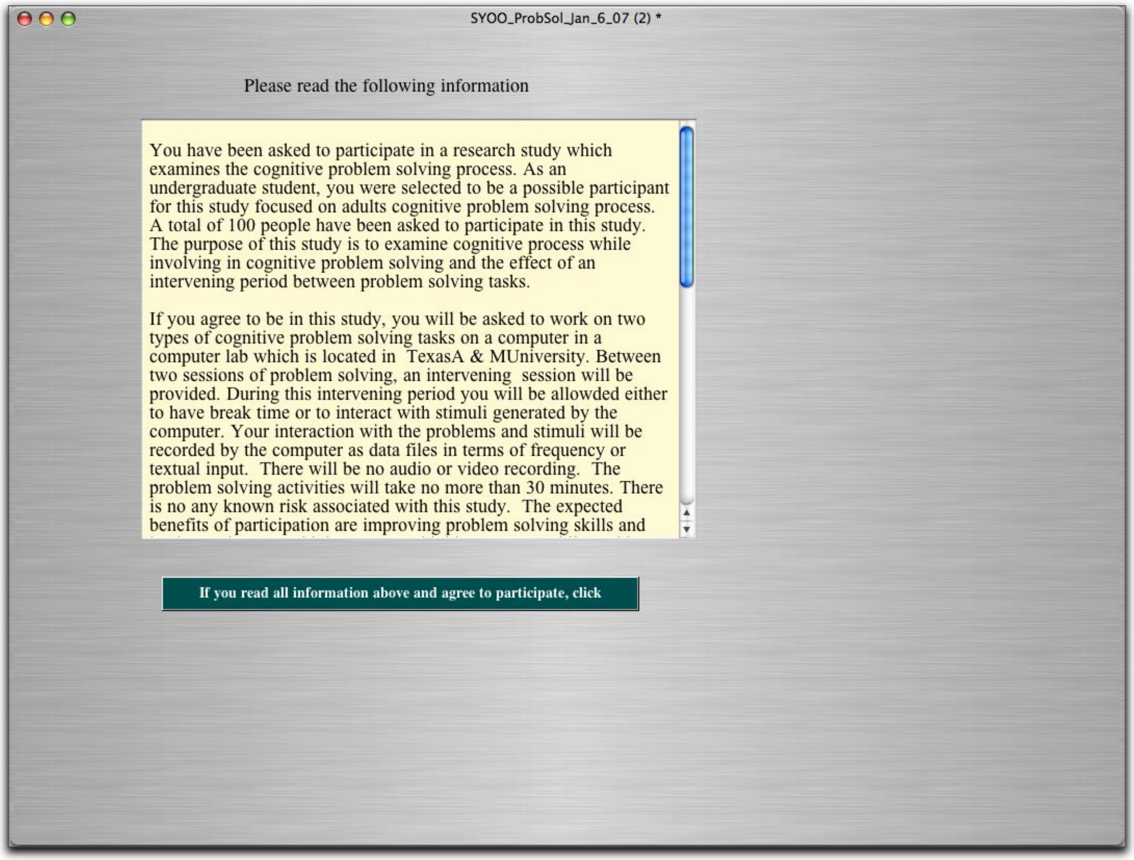
APPENDIX B

Initial Survey



APPENDIX C

Consent Information

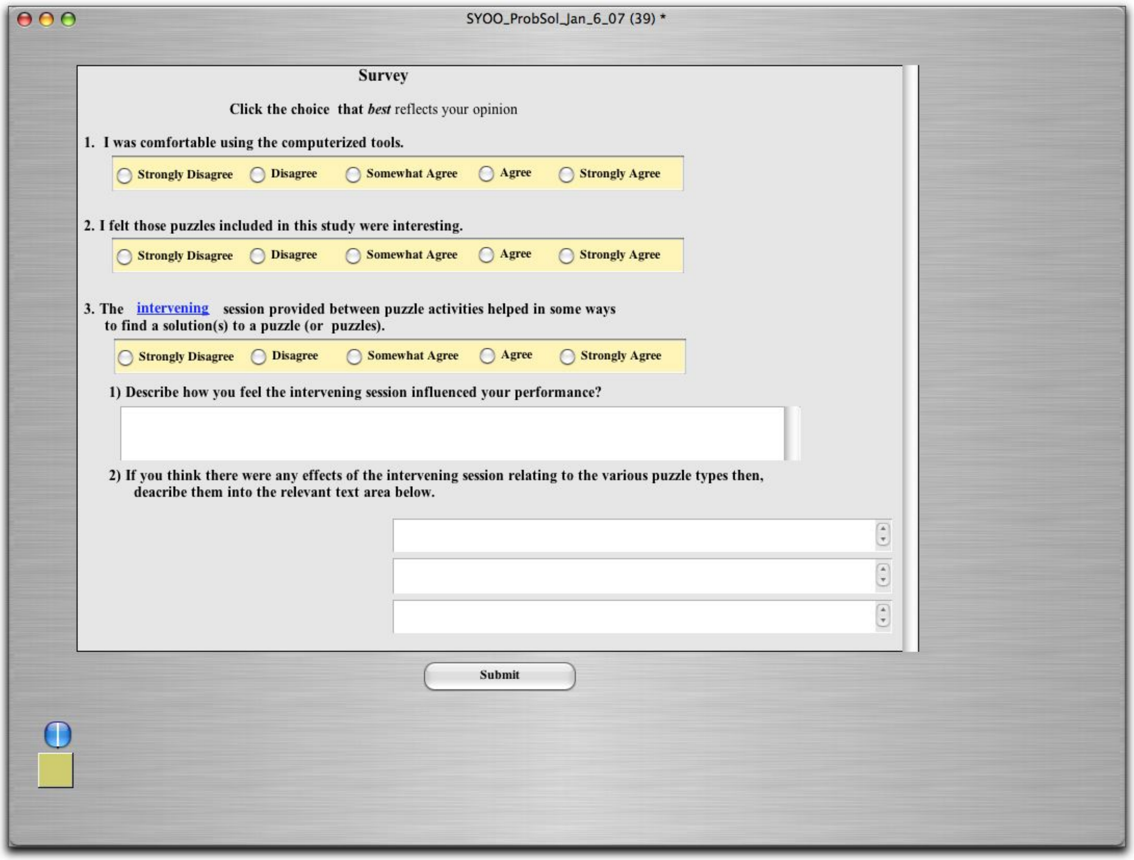


APPENDIX D

Introduction to the Activities

APPENDIX E

Final Survey



VITA

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