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EXPLORING INCUBATION EFFECTS ON INSIGHT PROBLEM-SOLVING WITH COMPUTER-BASED TASKS

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Abstract
This study examined the effect of interruption activities that were provided as an incubation period during computer-based problem-solving tasks. Incubation is an unconscious process and a crucial stage for a creative resolution when attempting to solve a problem. A computerized problem-solving environment was developed and utilized to automate the presentation of a set of problem-solving tasks and to record the subjects' interactions. One hundred eighty-five undergraduate volunteers were randomly assigned to one of six conditions. The findings support the view that experiencing an incubation period positively relates to problem-solving performance. Subjects resolved the problems more quickly when distracted by an intervening simple cognitive task than when allowed to work continuously. This implies that subjects can benefit from an interruption that involves visually and spatially changing stimuli and that also demands some degree of cognitive involvement.

Keywords: creativity; incubation; problem solving; computerized problem solving

Introduction

When students are confronted with an initial failure while trying to solve a problem, they may repeat their ineffective problem-solving approach again and again in vain. In this situation, a student may feel frustrated and see

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no alternative way to approach the solution. At this point, the student may continue to work on the problem or may decide to stop for a while and return to it later. The present study examines how students who are trying to solve problems in a computer-supported problem-solving environment may benefit from temporarily turning away from the problem at hand by focusing on another task before returning to the problem. Moreover, engaging in the intervening activity may contribute to the student's final resolution of the problem; this phenomenon is known as 'incubation'. Wallas (1926) introduced incubation as a crucial stage for a creative resolution to a problem. He suggested that the insightful moment of finding a solution comes about unexpectedly when a problem solver turns away from the problem and engages in other tasks or activities. He also suggested that incubation is an unconscious process. In accordance with Wallas' definition of incubation, Finke, Ward, and Smith (1992) described the incubated situation as follows: '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).

Psychologists have attempted to demystify the incubation phenomenon by explaining it in relation to memory processes (e.g., Sio & Ormerod, 2009; Smith & Blankenship, 1989, 1991; Smith, Ward, & Finke, 1995; Weisberg & Alba, 1981; Yaniv & Meyer, 1987). It has been argued that focusing on a new task rather than continuously and consciously working on the problem at hand helps the problem solver retrieve the crucial target information for the problem's solution. While taking a break or becoming involved in another irrelevant task, the problem solver may continue to search consciously or subconsciously through his or her mental knowledge network for the relevant information needed to solve the problem.

Thus, this period of alternative mental activity helps the problem solver gain insight into the solution. However, until recently, it was not easy to gather information on incubation activities during students' problem-solving processes. Computer-supported problem-solving environments have the potential to promote creative problem-solving skills through automated strategies and management functionalities related to the incubation moment when assessing a student's performance.

Experimental research on incubation

Existing empirical findings on incubation effects appear to contradict one another, making it difficult to draw general conclusions about the role of an incubation period in problem solving. Some studies have reported no effect or limited effects resulting from incubation sessions (e.g., Goldman, Wolters, & Winograd, 1992; Sio & Ormerod, 2009; Olton & Johnson, 1976; Vul & Pashler, 2007). Others have provided empirical evidence of incubation effects (e.g., Kaplan, 1989; Smith & Blankenship, 1989, 1991; Kohn, 2005; Sio & Ormerod, 2015). However, those studies have limits in identifying the effect of incubation on problem solving by including only a single type of problem to be solved (such as anagrams, rebuses, or dot problems). Sio and Ormerod identified in their meta-analytic the problem type and the incubation task as the modifiers of incubation effects. Also they argued that incubation effects are specific to particular tasks and performance conditions. Gilhooly and Murphy (2005) showed solving visual problems requires different types of cognitive processes from solving linguistic problems. Obviously, different types of problems may require different cognitive processes for their solution. For example, anagrams may require more algorithmic computation than rebus problems. Similarly, a particular type of interruption task may only produce incubation effects for certain types of problems; that is, it is possible that an incubation effect shown to be related to one type of problem may not be found for another type of problem. Consequently, there exists a need for involving different types of problems and incubation tasks in exploring incubation effects. Thus, the current study aims at improving upon the designs of past research by exploring the incubation effects of different types of interruption tasks for different types of problems, and doing so with a large sample size.

The mechanism of incubation

Previous research explains the incubation phenomenon as the result of relevant solution knowledge retrieval after a period in which attention is diverted from the problem at hand. Yaniv and Meyer (1987) conceptualized the underlying retrieval mechanism as a process of spreading activation in an associative knowledge network: knowledge is more accessible if it has been retrieved recently, and the activation is then spread to related knowledge in the associated knowledge network. This process is different from an algorithmic manipulation or trial-and-error search. The activation of knowledge spreads subconsciously as an individual continues searching after an initial unsuccessful attempt to retrieve knowledge. The initially activated knowledge continues to activate other associated knowledge (e.g., *tree* activates *family*, which activates *home*), trying to reach the target knowledge required for a solution to the problem even when the problem solver has physically turned away from the problem at hand. Incubation is considered to be the result of this subconscious spreading activation. However, this account of incubation seems to be more applicable to association problems (such as remote association or novel association problems) than to the spatial arrangement problems included in the incubation studies, such as dot connection, chain link connection, and coin arrangement.

Weisberg and Alba (1981) conceptualized incubation not as a period of total removal from the problem task, but rather as one in which some sort of residual problem-solving activity remains, with continuous activation of the memory of the problem components generating creative strategies for solving the problem. On this view, problem solvers benefit from an incubation period because they continue to work covertly on the problem during that period.

Another viable account of the mechanism of incubation incorporates the concept of fixation. On this account, incubation is regarded as resulting from the dissipation of a fixation or a mental block (Smith & Blankenship, 1989, 1991) that the problem solver experienced while actively searching for a solution to the problem. The fixation, which may have been the result of the subject's previous experiences or due to inaccurate assumptions about the problem, inhibited the subject from seeking a new approach (Smith, 1995). An interruption in the problem-solving activity can help the subject abandon an inappropriate approach and thus result in insightful awareness of a valid solution to the problem.

Computer-supported assessment in problem solving

In many educational settings, it may be difficult to gather student outcomes from working on actual problems for evaluation, because of time, space, and the context (Wang, Chang, & Li, 2008). For many reasons, computer-supported assessment in education has been growing. Computer-supported assessment allows students to be supported by advanced measurements and intervention strategies to assess and enhance their performance in complex or insight problem solving (Kim & Pedersen, 2011). Computer-supported environments enable instructors to gather more informative data and examine the quality of students' problem-solving outcomes. In educational assessment, obtaining systematic and theory-based evidence of a student's ability and skills is a fundamental activity. Computer-based assessment allows more efficient collection of changes in a student's outcomes and a detailed investigation of procedures of particular interest, and also provides a flexible setting in which problem-solving skills can be dynamically captured (Almond, Steinberg, & Mislevy, 2002; Eseryel, Ifenthaler, & Ge, 2011). For example, Wang et al. (2008) proposed automated grading methods with demonstrable coding and grading reliability for the assessment of creative problem solving in science education.

Objectives

The primary intent of this study was to examine the role of incubation in solving insight problems in computer-based tasks. This study defines incubation effects as improvements in the problem-solving performance of students who have worked on an interrupting task compared to those who continue to work on problems without being interrupted. The specific research question was "For each type of problem, do the interruption-task groups, combined and individually, perform differently on their problem-solving tasks after the interruption, compared to a continuously working group that has no interruption?"

Method

Participants and design

Two hundred two undergraduate volunteers at a large state university initially participated in this study. Only 185 subjects were included in the final analyses; those whose data were considered to inappropriately represent their abilities (i.e., who did not appear to actually try to work on the problems) were eliminated. Specifically, subjects were excluded if they responded with incorrect solutions (or provided no response) during both an initial and a final problem solving period, and they worked for fewer than -0.5 standardized units of time during the initial problem-solving period. The eliminated subjects were equally distributed across the study conditions. The subjects' ages ranged from 17 to 27.

The experimental design incorporated two control groups: (1) subjects who were presented with spatial problems (pattern changes) and no interruption task, and (2) subjects who were presented with verbal problems (anagrams) and no interruption task. Four treatment groups were included: these were respectively presented with (1) spatial problems and a verbal interruption task, (2) spatial problems and a spatial interruption task, (3) verbal problems and a verbal interruption task, and (4) verbal problems and a spatial interruption task. The subjects were randomly assigned to one of these six groups. Only between-group comparisons were considered, in order to preclude the potential confounds that a within-group design may cause (i.e., if 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).

Nine Macintosh computers with the OS X operating system were used to present the tasks and collect subjects' data. All subjects worked individually at a computer, and all computers presented the same visual interface. The subjects were randomly assigned to one of the nine computers upon entering the computer lab. The nine computers were programmed to start at different conditions and then loop through the sequence of six conditions, presenting a single condition to each subsequent subject, to ensure an equal number of subjects in each condition. Each subject was automatically provided with materials and activities in accordance with the experimental condition assigned by the computer, and each subject was provided with an orientation to the software functions at the beginning of his or her session. Thirty-minute experimental sessions were scheduled, each with a capacity for nine individuals. On average, 15 sessions per week were scheduled.

Materials

Problems

The three spatial problems that were adapted and computerized for presentation 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 three items: one problem was adapted from Finke, Ward and Smith's book (p. 172) and the other two were created for this study. The first spatial problem, the 10-coin problem, presented the subjects with a display of coins arranged in a pyramid pattern and then asked them to change the coins from that pattern to an inverted pyramid by making only three moves. Both the starting pattern and the required final pattern were illustrated at the top of the initial screen (*see* the left of Figure 1).

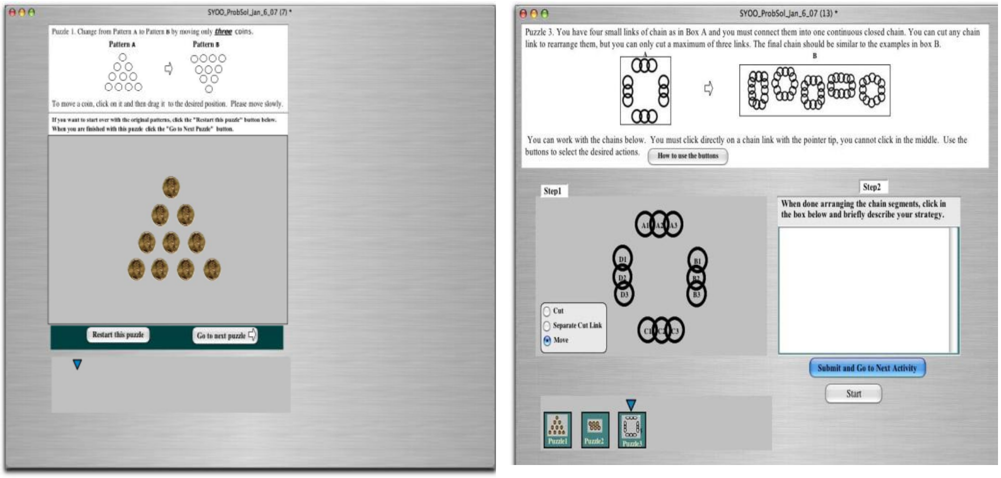

Figure 1. Screen displays of the 10-coin problem (left) and the chain connection problem (right) showing the general layout and contents of each

The second spatial problem, the 6-coin problem, was similar to the 10-coin problem in that it also involved transforming an original pattern (6 coins in two offset rows) to the goal pattern (6 coins in a circle) by making no more than three moves. However, this problem differed in that each move involved sliding a coin with constraints: (a) the 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 student was also required to arrange the coins in a specific final order according to the numbers labeling them (*see* Figure 2).

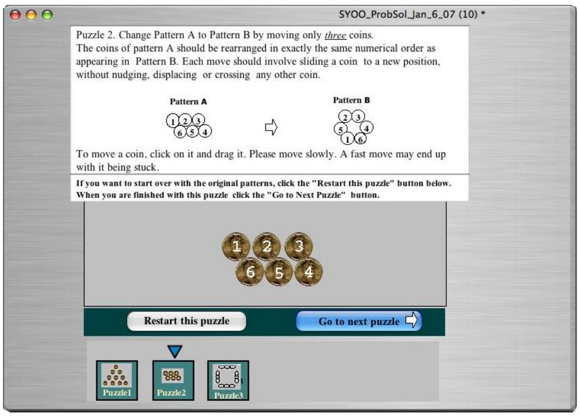

Figure 2. Screen display of the 6-coin problem showing details of the instructions and interactive components

The third spatial problem was a chain-linking problem in which subjects were presented with a display of four sections of three-link chains. To solve this problem, subjects had to connect the four chain parts to form a single circular chain by cutting open and reattaching only three of the links. Subjects could manipulate the chains by using the designated tools: ‘Cut’, ‘Separate-Cut-Link’, and ‘Move’ buttons that could be used to cut, unlink, or move the chain components. See the right half of Figure 1for a general view of this screen.

For each of the verbal problems (anagrams), the subjects were presented with a set of letters and requested to arrange them to spell a correct word. The subjects would then attempt to solve the problem by dragging and dropping the letters into the desired positions in the designated text field; a letter could be moved as many times as needed. The initial letter groups were (1) ‘RTEOH’, (2) ‘REARPOOT’, and (3) ‘PAT RUNS’. See Figure 3 for an illustration of the interface for these verbal problems.

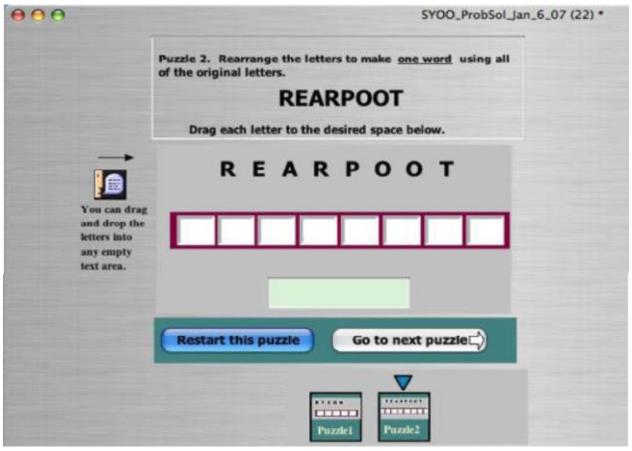

Figure 3. Dynamic interface for the second anagram problem. The initial letter set was 'REARPOOT' and the correct solution was 'OPERATOR'

Interruption Tasks

Verbal Interruption Task. The verbal interruption task presented a series of words in white text on a blue background. Each word was randomly selected by the computer from a pool of 20 words that started with the three-letter string 'str' and was presented for one second. The similarity among the words was designed to help create sufficient cognitive demand. After the presentation of a word, the subject was presented with a display of three words and asked to indicate which of the three words had just been flashed. The subject indicated the answer by clicking on the desired word, which caused the list to disappear. The next word was then presented after a random interval of two to five seconds, which required extra vigilance, as the presentation interval could not be predetermined. Each word was displayed for only one second. This task continued for five minutes (*see* the left of Figure 4 for visual details).

Figure 4. Interfaces for the verbal interruption task (left) and the spatial interruption task (right)

Spatial Interruption Task. The spatial interruption task required monitoring a visually complex screen background in which one of four geometric objects (a red triangle, red square, blue triangle, or blue square) appeared in random order and in random locations on the screen. Each object was presented several times, but always in a new location. Upon seeing an object, the subject was to respond immediately by clicking on the corresponding button; for example, when a red triangle appeared somewhere on the screen, the student was expected to press the button labeled 'Red Triangle'. Whether or not the subject responded, the next object appeared after a random interval of three to five seconds. The presentation sequence lasted for five minutes, and approximately 60 object presentations were made. See the right half of Figure 4 for a presentation of the interface for this activity.

Data recording

All of the subjects' interactions during the problem-solving sessions were monitored and recorded by the computer. For all problems, whenever a subject interacted with any object on the screen (e.g., moved a puzzle piece or pressed a button to select an option, request a new problem, or submit a choice), the response time, latency, and object name were noted and stored internally. The interactions during the interruption activities were similarly recorded. While the subjects were interacting with the verbal or spatial stimuli, their reaction times, their total number of responses, and the correctness of their responses were recorded. When the total time allotted for each problem session or interruption task session elapsed, the interaction data were saved as an external text file for further security of the data collection.

Problem-solving scores

The problem-solving data from the 185 subjects were analyzed. The subjects' performances were scored on both correctness and time spent on each problem. A correct solution to a problem received a score of 1, while an incorrect response received a score of 0. Thus, the highest individual score was three points. The time spent was computed by summing the time (in seconds) that a subject took while interacting with the three problems; this total did not include the time spent reading the problem instructions.

Procedures

At the beginning of each session, the computer provided the subjects with initial information about their participation in the experiment and their right to decline participation. The computer then illustrated the use of the interactive buttons in the program and described the time allotted for each activity. Next, the computer presented a survey designed to collect the subjects' academic level, major, gender and age. Each subject was then presented with the condition that was randomly assigned for his or her session. Consequently, half of the subjects worked on a set of three spatial problems and the other half worked on a set of three verbal problems. The time limit for each type of problem was established through previous pilot sessions that indicated that the spatial problems required a few minutes more for completion than the verbal problems. Accordingly, a total time of five minutes was allowed for solving the verbal problems and seven minutes for the spatial problems. After the initial problem-solving session, one third of the subjects in each of the spatial and verbal problem groups were presented with the verbal interruption task, another third were presented with the spatial interruption task, and the remaining third were given no interruption task. The verbal interruption task required responding to text displays, while the spatial interruption task involved responding to aspects of geometric shapes. After completion of the interruption task, all four interrupted groups were given a second session to solve the original set of problems. The control groups that were not interrupted were immediately presented with a second problem-solving session, with the same problems, after completing the initial session.

Results

Analysis 1: Spatial problems

The spatial problem-solving group consisted of 98 subjects. A descriptive analysis of the subjects' performance in each problem-solving session (as summarized in Table 1) indicated that in the initial problem-solving session, the No Interruption and Verbal Interruption Task groups scored slightly higher than the Spatial Interruption Task group in terms of the mean score: 0.91 for the No Interruption group, 0.91 for the Verbal Interruption Task group, and 0.85 for the Spatial Interruption Task group. On the other hand, in the final-problem solving session, the Spatial Interruption Task group performed slightly better than the other groups: 1.28 for the No Interruption group, 1.24 for the Verbal Interruption Task group, and 1.36 for the Spatial Interruption Task group.

Table 1. Means and standard deviations for spatial problem sessions

Group		Score[a] (Max 3 pts)		Time[b] (Max 420 sec)	
		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

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

To compare the groups' performances, a regression analysis was conducted. Since the individual score range was limited to between 0 and 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 the groups were made to determine (1) whether the Interruption Task groups together performed differently from the No Interruption (control) group and (2) whether the two Interruption Task groups performed differently from each other. There was not a statistically significant group difference on either the initial session score, F(2, 95)=0.06, p=.94, or the final session time, F(2, 95)=0.71, p=.50. The model used in this study is detailed in Figure 5 (CFI=1.0, SRMR=0.01).

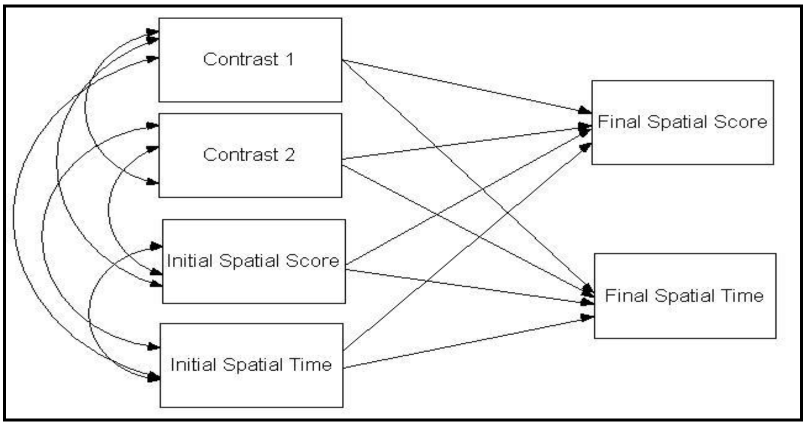

Figure 5. Regression model for the spatial problems. Contrast 1 compares the No Interruption group (coefficient: 2) with the two Interruption Task groups (coefficient for each group: -1). Contrast 2 compares the two Interruption Task groups (coefficients: Verbal Interruption Task = -1, Spatial Interruption Task = 1, and No Interruption = 0). A double-headed arrow between variables indicates that they are correlated

The correlation coefficients between variables are summarized in Table 2. 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). Contrasts 1 and 2 were associated with the final session time spent at the minimal level (r=.2 and .3, respectively).

Table 2. 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. Contrast 1[a]					__	.07
6. Contrast 2[b]						__

Note: [a] Comparison between the No Interruption group and the two Interruption Task groups; [b] Comparison between the Spatial Interruption Task and Verbal Interruption Task groups

As shown in Table 3, the results from the regression analysis indicated that the initial session score was an important predictor for the initial session time and the final session score, but the initial session time was not. Contrasts 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 the difference between the time spent in the initial problem solving and the time spent in the final session. The standardized regression coefficient of Contrast 1 on the time used was 0.22 ($t=2.40$, $p<.05$). This result indicated that the No Interruption group spent significantly more time than the Interruption Task groups. Based on Contrast 2, the performance of the two Interruption Task groups did not differ with respect to score but did differ significantly in time used. 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 between the initial and the final problem solving sessions are shown in Table 1. During the final problem-solving session, the No Interruption group spent an average of 13.2 seconds more than for the initial problem solving. On the other hand, the Interruption Task groups together spent an average of 32.4 fewer seconds during the final problem-solving session than during the initial problem-solving session. The Spatial Interruption Task group manifested the greatest decrease in time spent.

The different time uses of the groups were more obvious when they were compared in terms of the final problem-solving session's reduction of the time spent during the initial session. The subjects in the two Interruption Task groups spent much less time than those in the No Interruption group. Of the two Interruption Task groups, the Spatial Interruption Task group showed a greater time reduction 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 Task groups spent much less time during the final problem-solving session than during the initial problem-solving session. See Figure 6.

Table 3. Regression estimates for the final spatial performance score and time

	B	*SE*	*t*	ß
Criterion: Final Session Score				
Contrast 1	-.25	.24	-1.02	-.09
Contrast 2	-.01	.05	-0.22	-.02
Initial Session Score	.54	.09	5.79**	.53**
Initial Session Time	.01	.01	.35	.03
Criterion: Final Session Time				
Contrast 1	75.44	31.40	2.40*	.22*
Contrast 2	17.21	6.22	2.77**	.25**
Initial Session Score	-7.95	12.60	-.63	-.06
Initial Session Time	.13	.14	.96	.09

Note: $R^2 = 0.28$ for the final problem-solving score; $R^2 = 0.13$ for the final problem-solving time; $^*p < .05$. $^{**}p < .01$

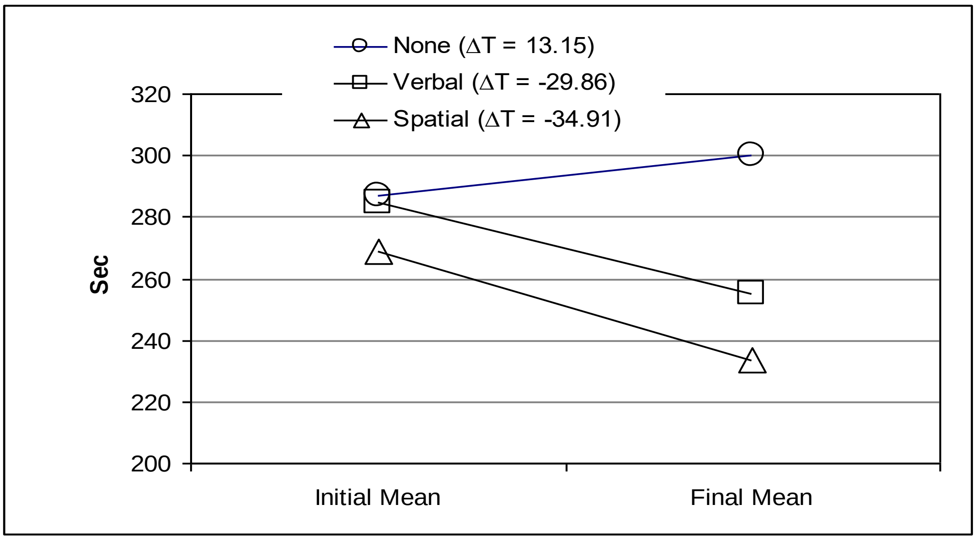

Figure 6. Average time spent by the groups during the initial and final problem-solving sessions for the spatial problems

Analysis 2: Verbal problems (Anagrams)

This analysis included data from 87 undergraduate students who worked on the verbal problems. The method used to analyze the spatial problems was also applied in this analysis. The general performances of the groups are summarized in Table 4. During the initial problem-solving session, the mean scores of the No Interruption and Spatial Interruption Task groups were slightly higher than that of the Verbal Interruption Task group: 0.90 for the No Interruption group, 0.59 for the Verbal Interruption Task group, and 0.83 for the Spatial Interruption Task group. There was not a statistically significant group difference on either the initial problem-solving score, $F(2, 84)=1.71$, $p=.19$, or the final problem-solving time, $F(2, 95)=0.25$, $p=.78$. In the final problem-solving session, the No Interruption and Spatial Interruption Task groups scored slightly higher than the Verbal Interruption Task group as well: 1.21 for the No Interruption group, 0.90 for the Verbal Interruption Task group, and 1.03 for the Spatial Interruption Task group.

Table 4. Means and standard deviations for verbal problems

Group		Score[a] (Max 3 pts)		Time[b] (Max 300 sec)	
		Initial	Final	Initial	Final
No Interruption (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

Note: [a] Sum of the item scores on the verbal problems; [b] Total seconds that an individual spent interacting with the problems

Contrast 1 compared the No Interruption group with the two Interruption Task groups. Contrast 2 compared the two Interruption Tasks groups. The correlation matrix for the variables showed a positive relationship between the initial and the final session scores (r=.72) and between the initial and the final problem-solving times (r=.34). On the other hand, the initial problem-solving time was negatively correlated with both the initial problem-solving score (r=-.30) and the final session score (r=-.30). See Table 5 for details. This result indicated that the subjects who spent relatively more time in the initial session were less likely to find the solutions to the verbal problems in the final session. This result was contrasts with the finding from the previous analysis of the spatial problems that the time spent for the initial problem-solving was not correlated with the scores on the final problem-solving.

Table 5. 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. Contrast 1[a]					__	*.04*
6. Contrast 2[b]						__

Note: [a] Comparison between the No Interruption group and the combined Interruption Task groups; [b] Comparison between the two Interruption Task groups

When the final session score and the final session time were regressed on the predictor variables using the MLM method, the initial problem-solving score and the initial problem-solving time were both identified as significant indicators 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 6 for details.

Table 6. Regression estimates for the final verbal performance score and time

	B	*SE*	*t*	ß
Criterion: Final Session Score				
Contrast1	.16	.25	.67	.05
Contrast 2	.01	.04	.18	.01
Initial Session Score	.96	.10	10.04**	.76**
Initial Session Time	.01	.01	3.21**	.21**
Criterion: Final Session Time				
Contrast 1	-31.38	28.04	-1.12	-.10
Contrast 2	7.86	6.06	1.30	.13
Initial Session Score	-20.61	12.01	-1.72	-.16
Initial Session Time	.52	.22	2.38*	.29*

Note: R^2 = .56 on the final session score; R^2 = .16 on final session time; p < .05; ** p < .01

Conclusions

Incubation involves taking a break in problem solving when a student needs more creative solutions that will deliver better results. Theoretical and experimental studies have shown that developing a strategic skill or intervention process is necessary to improve student competencies in authentic and creative problem solving. Thus, the incubation phenomenon needs to be studied to understand which instructional interventions or processes are effective for solving problems. In the present study, students participated in sequential sessions of tasks and interruption activities in computer-based tasks that presented problems based on the experimental design and that recorded students' interactions during the problem-solving tasks. The study's goal was to examine the effect of interruption activities that were provided as an incubation period in this environment.

The research question was: 'For each type of problem, do the two interruption-task groups, combined and individually, perform differently on their problem-solving tasks after the interruption, compared to a continuously working group that has no interruption? To answer this question, incubation effects were defined as better performance by the interruption-task groups than the control on problem-solving performance scores (higher scores). For the spatial problems, the performance of the combined interruption-task groups in terms of response accuracy did not differ from that of the continuously working group. However, the time spent by the combined interruption-task groups was different from of the time spent by the continuously working control group; specifically, the interruption-task groups spent much less time than the continuously working group.

The findings might also indicate that the subjects who worked on spatial problems could figure out the solutions more quickly during the final session when they were distracted by an interruption task, compared to those who did not have an interruption task. This assertion is supported by the result of comparing only those members of each group who were not successful during the initial session but who figured out the solutions for spatial problems 1 and 2 during the final session (resolvers). The performance on the third spatial problem was not taken into account because of its much lower resolution rate than the other two problems.

The results of comparing only the performance of those who solved the problems during the final session indicated that the solution 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 of the three groups, which was consistent with the previous analyses of the performances of the groups. Therefore, these results implied that given the similar solution rates across the groups, the subjects who were working on the second session of spatial problems arrived at 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.

On the verbal problems, the combined interruption-task groups did not show a significant performance difference from the control group in terms of response accuracy. The response time for the combined interruption task groups was slightly less, although not at a significant level, than for the control group. When the two interruption-task groups were compared in terms of the time spent to solve the problems, it was found that the spatial-interruption group used slightly less time than the verbal-interruption group for both types of problems. This observed difference in performance for the two types of problems may be due to the different processes required for these types of problems. The solutions to the spatial problems all require transforming an original arrangement to another. Thus, perceptual restructuring of the patterns could be a key process for solving the problems. According to Bowden (1997), restructuring of a problem representation is the crucial ingredient of insight. In contrast, the processes involved in working with the verbal problems are generally regarded as including both forward-thinking and illumination processes (Finke, Ward, & Smith, 1992). More recently researches have tried to account for insight in terms of memory process. Insight is typically considered as being associated with an automatic, intuitive, and unconscious process that is likely to be less interfered with working memory, while solving non-insight problems involves a more conscious, sequential process highly correlated with working memory (Baddeley, 2000; Gilhooly & Murphy, 2005; Stanovich & West, 2000). This may also imply that the two types of tasks included in this study are associated with different levels of restructuring in the problem representation. Weisberg (1995) sorted tasks into those requiring restructuring (pure-insight), those that do not involve restricting (non-insight), and hybrids that may or may not involve restricting. Thus, working with the spatial problems might be more associated with the process of insight than working with the verbal problems. Put another way, the 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, the performance gap between the two types of problem-solving may be attributable to the subjects' different levels of learning from the initial to the final session for the two types of problems. During the second problem-solving session, individuals in the verbal problem-solving group may have been more likely to remember their first session than individuals in the spatial problem-solving group. For example, a subject may be less likely to forget the word(s) that he/she previously tried to spell with the letter stimuli in an anagram problem, while a subject may be more likely to forget a complex solution sequence that he/she had tried for solving a coin rearrangement problem in the initial session. The high consistency in the subjects' problem-solving performances shown on the verbal problems may support this interpretation. Thus, future studies should include different sets of problems for the final session in order to control the potential differential effects of remembering the initial problem-solving activities.

The findings from the present study partially support the contention that subjects can benefit from an interruption task when finding solutions to insight problems. Thus, the findings suggest that a subject can solve a problem more quickly when temporarily interrupted by a simple cognitive task. Additionally, the study results imply that a subject can benefit from an interruption task that involves stimuli changing in attributes and locations. The subjects in this study were faster in solving problems when interrupted with tasks involving stimuli changing in attributes and location than they were when given tasks involving only stimuli without such changes.

Limitation and future research

The present study used the same set of problems for both the initial and final problem-solving sessions. Thus, the subjects saw the same problems during both sessions. It was possible, particularly for the verbal problems, that during the final session the subjects remembered how they responded to the problem they saw during the initial problem-solving session. In later studies this problem can be addressed by employing a different set of problems, but of the same type, during the final problem-solving session. It is also important to note that the majority of the subjects were education majors. Therefore, the results may be specifically applicable to education majors. Future studies should 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 subjects from fully demonstrating their problem-solving ability. Based on the researcher's observations, there were one or two cases where some of the components of the coin puzzle problems did not work smoothly. On a survey question integrated into the computerized assessment, a few students pointed out that the objects in the chain-linking question did not move smoothly as they had desired. Such technical features also need to be addressed for future studies.

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