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Incubation in Insight Problem Solving

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ABSTRACT: A break in the attentive activity devoted to a problem may eventually facilitate the solution process. This phenomenon is known by the name incubation. A new hypothesis regarding the incubation mechanism is suggested. It is based on analysis of the structure of insight problems and their solution process. According to this hypothesis, no activity takes place during the break. The break's only function is to divert the solver's attention from the problem, thus releasing her mind from the grip of a false organizing assumption. This enables the solver to apply a new organizing assumption to the problem's components upon returning to the problem. The numbers of experimental studies that confirm the existence of the incubation phenomenon, and those that do not support it, are roughly equal, thus the primary experimental aim of the study is to improve the methodology of manipulating the break. This was done by starting the break only after an impasse has been reached. The results indicate that the break improves performance in insight problem solving, but its length does not make a difference. This supports the suggested hypothesis and does not support hypotheses that postulate unconscious ongoing processes during the break.

Taking a break while struggling to solve a problem may help to solve it. This phenomenon is called *incubation*, and it marks the second phase of the creative process according to Wallas (1926), who described the stages of preparation, incubation, illumination and verification. The term *incubation* is biased in favor of the most popular explanation of the phenomenon, suggesting that a gradual and continuous unconscious process is going on during a break in the attentive activity toward a problem. However, there are other explanations of this phenomenon. It is possible to divide incubation hypotheses into two classes. The first describes autonomous internal solving processes. The second describes the influence of external cues on the solution process during the break.

Autonomous-Processes Hypotheses

Henri Poincaré, the famous French mathematician, hypothesized that an internal entity called the "subliminal self" unconsciously blends the mental atoms of our mind (ideas). When an interesting, relevant, and aesthetic combination is formed, it breaks into consciousness (Poincaré, 1929). There are few modern followers to Poincaré's unconscious hypothesis. Some of them suggest an evolutionary unconscious mechanism that includes the creation of random recombinations of ideas, and the selective retention of the best of them (Campbell, 1960; Simonton, 1995). According to others, unconscious integration of knowledge takes place through spreading activation processes in the mnemonic associative networks, in a continuous and cumulative fashion (Bowers, Regher, Balthazard, & Parker, 1990).

A less popular hypothesis is that of nineteenth-century scientist Hermann Helmholtz who suggested that the break simply gives the solver an opportunity to rest (described in Woodworth, 1938). This explanation is called the *fatigue-dissipation hypothesis* (Seifert, Meyer, Davidson, Patalano, & Yaniv, 1995).

Woodworth (1938) himself suggested that during the break, false assumptions that block the solution process may decay, thus enabling the solver to return to

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the problem with a fresh look. According to the *selective forgetting hypothesis*, which is a developed version of the Woodworth's hypothesis, the decay of irrelevant material occurs in the working memory during shifts of attention away from the problem, while the long-term memory accumulates more substantial information (Simon, 1966, 1977).

External-Cues Hypotheses

Several models (Langley & Jones, 1988; Seifert et al., 1995; Yaniv & Meyer 1987) closely follow Louis Pasteur's declaration that "chance favors the prepared mind" (cited in Posner, 1973, p. 148). According to these models, the role of the break is to enable the mind that had been busy studying the problem, to encounter and assimilate external cues from the environment. Yaniv and Meyer (1987, p.200) explain this notion as follows: "According to this hypothesis, the initial unsuccessful attempts to solve the problem may partially activate stored memory traces, critical to the problem's solution, that have been inaccessible. Then, during a subsequent intervening period involving other endeavors, the activation may sensitize a person to chance encounters with related external stimuli that raise the critical traces above threshold level, and trigger their integration with other available information."

The Attention-Withdrawal Hypothesis

A new explanation, drawing on both classes of hypotheses, will be suggested here. It is based on analysis of the structure of insight problems and their solution process.

It seems that insight problems are the very tool for investigating incubation phenomena. Two prominent characteristics, that are both phenomenological and behavioral, distinguish insight problems from problems that are solved solely by gradual and continuous processes. The first one is the *impasse* that one encounters while trying to solve an insight problem (Durkin, 1937; Ohlsson, 1992). The second is the *"Aha!" experience* that expresses the suddenness of the solution and the solver's surprise from breaking the impasse (Duncker, 1945; Maier 1930; Metcalfe & Wiebe, 1987). After encountering an impasse, people spontaneously tend to divert attention from the problem, thus having a break that may eventually help them. On the other hand, taking a break while solving a problem that must be solved only by a gradual and continuous process is a senseless move that only impairs the solution process or at least delays it.

Some gestalt psychologists noticed that participants tend to fixate on a false assumption when trying to solve an insight problem, and that in order to solve it, one has to form the correct assumption instead (Scheerer, 1963). This act involves a restructuring of the problem elements (Kohler, 1947,1969; Wertheimer, 1959) or—in information processing terms—changing the representation of the problem (Gick & Lockhart, 1995; Kaplan & Simon, 1990; Ohlsson, 1984a, 1984b).

But why must one assume any assumptions at all in order to solve an insight problem, and why do solvers almost always assume false assumptions? Whether an assumption is false or correct, it is not another piece of information, but rather an organizing agent that connects all the elements of the problem to each other and thus enables the solver to understand the problem and to act upon it. Without an organizing assumption, the problem would not be formed in the mind of the solver in the first place, and changing it would change the way one represents the problem. The organizing assumption has another critical function: It directs the attentive activity of the solver into closed borders, or in other words, into a bounded problem space. When the organizing assumption is false, it is impossible to reach the solution within the limits of the false problem space.

Insight puzzles are cleverly made up. They take advantage of the tendency of the cognitive system to rapidly hang onto the first organizing assumption that comes to mind, in order to misdirect the solver into a false problem space. The inventor of an insight puzzle finds a complete mental structure that is fully organized by one organizing assumption (the correct one), but whose elements could be also structured only partially by another organizing assumption (the false one). The inventor then manipulates the presentation of this structure, usually by omitting or adding information, to mislead the solver into assuming the partial organizing assumption that leads to an impasse, thus creating the puzzle. Once the solver assumes the false assumption, she is trapped in attentive activity inside a deficient problem space, directed by the false assumption; this is the cause of fixation. The larger the deficient problem space (resulting in more opportunities for action within its boundaries), the longer the fixation will persist.

Take, for example, the following insight puzzle: How can a cake (usually depicted as round) be cut into eight pieces of equal size with only three cuts (Walberg, 1980)? It is quite easy to dissect a cylinder into eight equal parts. The mental act of division will probably be smoothly organized and complete in the mind of the performer. However, if we disguise the cylinder as a cake, the solver will be misled into assuming that the cuts should be made only in the common way of cutting a cake—from the top. When the solver subjectively exhausts the false problem space of trying to cut the cake from the top, she will be ready to change the organizing assumption and think also of a horizontal cut along the middle plane of the cake.

To solve an insight puzzle, the solver must escape from the mental activity governed by the false assumption inside the deficient problem space. That could be achieved by a delicate mental condition that allows, on one hand, a withdrawal of the attention governed by the false assumption, and, on the other hand, some level of activation of the problem's elements in the solver's mind. The presence of the problem's elements in the mind—not anymore constrained by the relations forced by the false assumption—provides the solver an opportunity to apply another structure to these elements, this time governed by a different assumption that may lead to the right solution.

This mental condition can appear on three occasions. The first is right after the impasse. The second, which involves the external environment, may take place during the break. The third, which depends solely on the internal solution process, would occur upon returning to the problem after the break. Only the third occasion will be examined here experimentally.

The First Occasion

Right after reaching the impasse, before the solver's attention is fully diverted from the problem, the solver's mind begins to wander. In this situation, the elements of the problem are still present in the mind, but the false assumption begins to lose influence.

The Second Occasion

The *prepared-mind hypothesis* argues that the break allows the solver to encounter external cues after the initiation of the solution process. According to the *attention-withdrawal hypothesis*, increased activation of the relevant components is, indeed, necessary, but no less necessary is the diminished activation of inhibiting components. From the prepared-mind perspective, it does not matter if the cue appears during the break or during attentive work on the problem, as long as the relevant components were activated enough through coping with the problem. In contrast, according to the *attention-withdrawal hypothesis*, before reaching the impasse the chances for assimilating a cue are low, because during that time the false assumption confines the solver to mental regions of activity and perception that do not lead to solution. On the other hand, during the break, the influence of the false assumption is diminished and relevant cues may cross the borders that were placed previously by the mind.

The Third Occasion

The third occasion offers an internal account to the incubation phenomena that does not depend on the external environment. This explanation follows the attention-withdrawal hypothesis and will be called the *returning-act hypothesis*. According to this hypothesis, no process evolves during the break. The break's sole function is to divert the attention of the solver from the problem, thus reducing or erasing the activation of the false assumption. Re-encountering the problem when the break terminates poses an increased chance for solution. At this point in time, the elements of the problem will be for a pre-attentive moment—before being subject to any organization—released from the organization of the false assumption and, metaphorically speaking, free floating in the mind. The solver may reassume the old assumption, but the odds for doing so are lowered now, because this assumption did not work previously. Thus, one may now apply the correct organizing assumption to the problem elements and build from them a complete structure that will constitute the solution.

The Research Goals

Despite widespread anecdotal reports of breakthroughs attributed to incubation, which now belong to the scientific lore, rigorous experimental verification of the incubation phenomenon is far from trivial.

Roughly, the number of experiments that found incubation effects and those that failed to do so is even (for review see Dorfman, Shames & Kihlstrom, 1996; Smith & Blankenship, 1991). Thus, the first goal of this experiment is to generate optimal conditions for the appearance of incubation.

The timing for starting the break is usually determined arbitrarily. This procedure reduces the chances of success of the incubation phase. If the break occurs before reaching the impasse, then the exploration governed by the false assumption would not have been exhausted, and the solver would not be ready to change that assumption at the point of return to the puzzle. If the break occurs after reaching the impasse, the experiment will probably lose participants who succeeded in solving the puzzle due to a spontaneous break after reaching the impasse. Therefore this study used a new technique, in which the break begins exactly upon reaching an impasse.

The phenomenon of incubation and the consequent emergence of insightful solution are sensitive to a multitude of variables, including random and individual factors. To eliminate such sources of noise, one typical clear-cut insight puzzle was chosen as the preferred tool for this study, as has been done in previous investigation in this area (Dominowski & Jenrick 1972; Dreistadt, 1969; Olton & Johnson, 1976; Murray & Denny 1969). Such a puzzle is characterized by a compelling impasse and a full insight leading to the solution. Full insight, following Koffka (1935) and Ohlsson (1992), is characterized by the completion of the restructuring process simultaneously with the discovery of the correct representation or immediately following it. In case of a partial insight, further gradual attentive process is required. The full insight may facilitate the participants' ability to pull themselves out of the grip of the false assumption upon returning to the problem.

The second goal of the study is the examination of the *returning-act hypothesis* as compared with other *internal-process hypotheses*. The later, namely, the *unconscious hypothesis* and the *selective-forgetting hypothesis* both argue for a continuous mental process during the break. Therefore, they predict that the longer the break, the better the performance will be. In contrast, the *returning-act hypothesis*, which emphasizes the instant of restructuring at the end of the break, argues that the break only serves as a strong diversion from the influence of the false assumption. It predicts that the break will improve performance, but that there will be no difference in performance under different lengths of the break. Hence the problem-solving performance under two different lengths of incubation intervals was compared with a no-break condition.

The type of task performed during the break may be important. Because the *returning-act hypothesis* argues that the break serves as a diversion from the influence of a false assumption, it predicts that strong diversion during the break will facilitates incubation effects, but weak diversion will be associated with no effects or smaller ones. In contrast, the *unconscious hypothesis* does not predict a difference in performance contingent on different tasks. Consequently, the design comprised two interval lengths that were either occupied by demanding task or filled with a nondemanding activity.

Method

Participants

The study included 147 undergraduate students, about equally divided between both sexes. These were students from the Faculty of Social Sciences at the Hebrew University of Jerusalem, who got credit for participation in psychological experiments. All participants were tested individually. Among them, 43 solved the problem before reaching an impasse and were not considered in the results. The 104 remaining participants were randomly assigned to five groups.

Materials

The insight puzzle that was used is presented in Figure 1. The verbal presentation of the puzzle guides the participants to compute separately the area of the square and that of the parallelogram. For most of the solvers this problem representation makes the solution too difficult. Usually they fail to see that *a* is the altitude of parallelogram EBGD and tend to calculate its area in other futile means**.** The solution can be easily achieved through restructuring the given shape into two partially overlapping triangles: ABG and ECD. The sum of their areas is $2 \times ab/2 = ab$. Moreover, once the insight of perceiving the required area as that of the sum of the two triangles is achieved, one can easily see

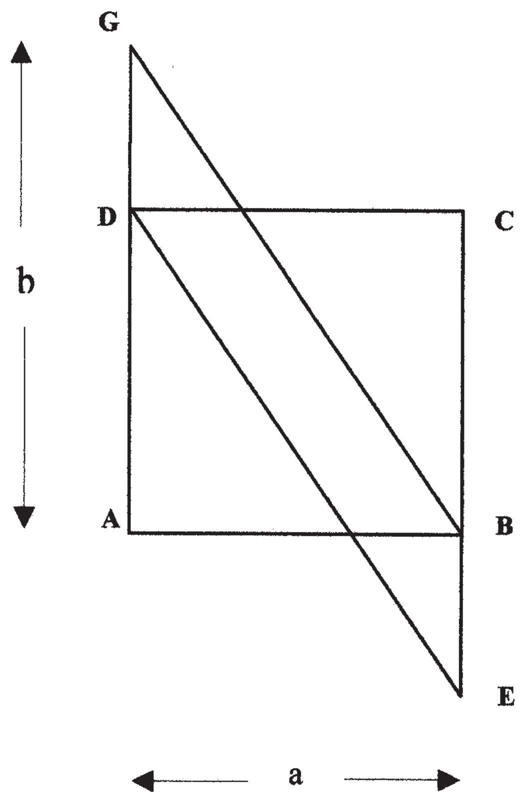

Figure 1. *Given that $\overline{AB}$ = a and $\overline{AG}$ = b, find the sum of the areas of square ABCD and parallelopgram EBGD (Ohlsson, 1984b).*

that by shifting one of the triangles so that DE coincides with GB, the answer is ab, the area of the resultant rectangle.

Design

Combining the three break lengths (long, short, and no break) with the two levels of activity during the break (demanding task and nondemanding task) resulted in five experimental conditions: short-break–demanding task; long-break–demanding task; short-break–nondemanding task; long-break–nondemanding task; and no-break, that served as control for all break conditions. The breaks in the long-break conditions (12 min) were three times longer than the breaks in the short-break conditions (4 min). The breaks started only when an impasse has been achieved. At the end of the break, in all the break conditions, participants returned to work on the problem (for at most 6 min). In the no-break condition continuous work on the problem went on for another 6 min or until attaining a solution. The dependent variable was the proportion of solvers out of all participants in a given condition.

Procedure

The participants were each given a sheet of paper with the puzzle. They were instructed to notify the experimenter in case they solved the problem, or if they felt stuck or failed to progress. Otherwise, they could work on the problem for up to 20 min in the initial working stage. Participants who solved the puzzle during this stage were released. Those who felt stuck or who had exhausted the entire 20 min were randomly assigned to one of the five experimental groups (all those who exhausted the full 20 min admitted that they felt stuck).

The next stage continued as follows: In the four break groups, all the papers that the participants used were collected by the experimenter. Then, in the demanding-task groups, participants worked on a crossword puzzle for 4 or 12 min, depending on whether they belonged to the short- or the long-break group, respectively. In the nondemanding task groups, participants leafed through newspapers for 4 or 12 min, respectively. Afterwards, in all four groups, the papers that participants had used were returned to them, and they tried to solve the puzzle for another 6 min. At the end of this interval the proportion of the solvers in each group was examined. In the no-break group, participants continued to work on the puzzle for additional 6 min after reaching the impasse.

Predictions

The returning act hypothesis predicts that both the short-break and the long-break conditions would show an improvement in performance relative to the no-break condition, but that no difference will be found between the two break lengths. The unconscious hypothesis and the selective-forgetting hypothesis both describe a continuous process during the break, and therefore they predict that the improvement relative to the no-break condition will be higher in the long-break conditions than in the short-break conditions.

The returning act hypothesis also predicts that although the demanding-task conditions will show incubation effects, it is doubtful whether the nondemanding task will show comparable effects, because the diversion during the break is weaker. In contrast, the unconscious hypothesis is indifferent to the type of task that is performed during the break.

Results

The size of the incubation effects was summarized by a phi coefficient (Hays & Winkler, 1971, pp. 802–804) between the dichotomous variables of solving (not solving) the puzzle and breaking (not breaking) the attentive work (a chi-square test for independence indicates the level of significance).

To rule out the possibility of influence of the time period before reaching the impasse on the success of solution, a point biserial correlation coefficient (Friedman, 1968; Guilford, 1956) between these two variables was computed across all 104 participants. It was found that $r_{pb} = -0.04$

The proportion of solutions in the no-break group was the lowest: 0.1 ($n = 20$), lower than the proportions in all four break groups.

Demanding task. The proportions of solutions in the short-break group, 0.43 (n = 21), and the long-break group, 0.40 ($n = 20$), were similar. The measures of the break effect on solving the puzzle were $\phi = 0.37$, χ^2 (1) = 5.63, $p < 0.02$, for the short break, and $\phi = 0.35$, χ^2 (1) = 4.80, $p < 0.05$, for the long break.

Nondemanding task. The proportions of solutions in the short- and long-break groups were 0.35 (n = 20) and 0.26 ($n = 23$) respectively. The measures of the break effect on solving the puzzle were $\phi = 0.30$, χ^2 (1) = 3.58, $p = 0.058$, for the short break, and $\phi = 0.21$, χ^2 (1) = 1.83, *ns*, for the long break.

The complete pattern of results is presented in Figure 2.

Discussion

Because the literature does not present conclusive evidence for the existence of the incubation phenomenon, the first goal of this study was to set the appropriate conditions for finding incubation effects. To do that, a typical insight puzzle was used, and the breaks started only after an impasse has been reached. Indeed,

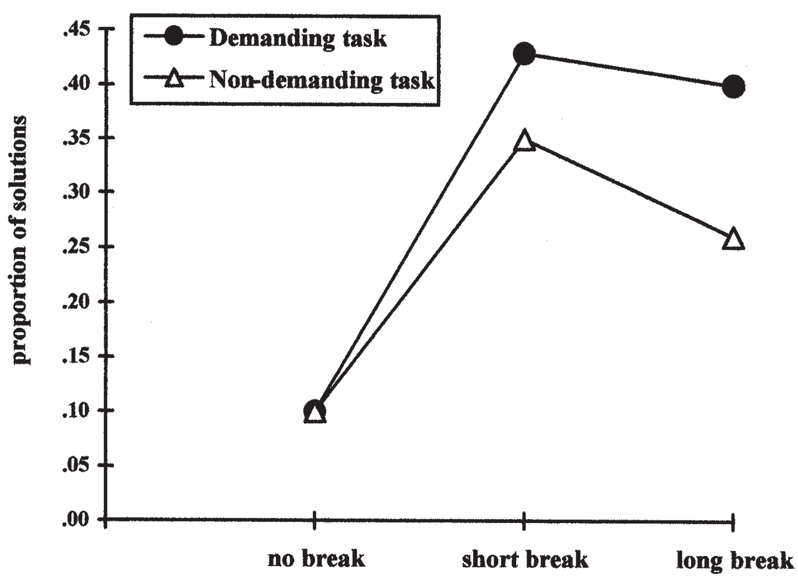

Figure 2. *Proportion of solutions in the groups of demanding task and nondemanding task according to the length of the break.*

incubation effects were found under some conditions. These effects match the predictions of the returning act hypothesis, and not the predictions of other internal-process hypotheses.

According to the returning act hypothesis, nothing happens during the break. The break only serves as a diversion from the influence of the false assumption. This diversion enables the solver to apply a new organizing assumption when reencountering the components of the problem that, for a preattentive moment, are found in an unorganized state. Therefore, this hypothesis predicts that a break would improve the performance in insight problem solving, but that the duration of the break would not influence performance. That prediction fits the demanding task pattern of results: both the long- and the short-break demanding task groups yielded better performance than the no-break group, and were close to each other. This pattern of results does not fit the prediction of other hypotheses, such as the unconscious hypothesis and the selective-forgetting hypothesis, that postulate a continuous process during the break and predict a greater effect for long breaks. These results also contradict the fatigue-dissipation hypothesis, because participants did not rest during the break.

The pattern of results for nondemanding tasks is similar, but the effects are weaker. Apparently, the less demanding activity during the break serves as a weaker diversion from the influence of the false assumption. These results, too, fit the prediction of the returning act hypothesis, and not the prediction of the unconscious hypothesis.

The results clearly show that the break produced an improved solving performance. Whatever would be the cause, it could not be due to an ordinary attentive process on the problem, because participants in the break groups were occupied by another attentive activity during the break. Thus, the goal of an experimental confirmation of the incubation effects has been achieved. Taking a distracting break when running into a dead end (impasse) in the solution process, and then returning to the problem, proved more efficient than working continuously for the same net duration.

The unconscious hypothesis was not supported by this research. I am inclined to believe that the popularity of unconscious explanations of incubation among scientists and laymen stems from the incorrect interpretation of the phenomena of the impasse and the "aha!" experience. It is easy to get the impression that upon arriving at an impasse the solver is far from solution, and later, when having the insight, the full solution comes to mind at once. According to this line of thought, the mind must have performed a great deal of cognitive work that the solver was unaware of between these two occasions.

But these notions are probably wrong. When the solver reaches the impasse in a typical insight puzzle that requires a full insight, the completion of the solution might be very close. In fact, only one ingredient is missing—the correct organizing assumption. All the components of the solution are already there, at the impasse point, "waiting" for the correct organization, which is concealed by a false organization. Once the false organization is removed, whether it be by distraction or forgetfulness, the correct organization may take its place.

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