Incubation in Problem Solving as a Context Effect

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Abstract

Anagrams were used to test the hypothesis that incubation is the result of a change in context between two attempts at a problem. The context was manipulated between two sessions of work on the anagrams by presenting word searches containing words from a single category (either animals or fruit and vegetables) prior to each session of problem solving. Some of the anagrams had solutions from one of these two categories; these were compared with distracters, the solutions of which belonged to neither category. The anagrams subject to the context manipulation showed an incubation effect (superior performance for items attempted in two sessions relative to controls attempted in only one session) whereas distracters did not, thus supporting the hypothesis.

Introduction

Despite an abundance of anecdotes, the incubation effect has proved elusive in controlled experiments. The experience of leaving a difficult problem for a period of time, then finding that the difficulty evaporates on returning to the problem, or even more striking, that the solution comes "out of the blue" (the insight experience) when thinking about something else, is widespread. Many guides to effective thinking and problem solving advise the reader to set problems aside for a time.

The most widely adopted paradigm for investigating incubation involves comparing problems on which participants take a break during solving with problems on which participants work for a continuous period. The total time spent on each problem is equated across the conditions and the incubation period is usually filled with an unrelated activity to prevent further conscious work on the problem (e.g. Fulgosi & Guildford, 1968; Kaplan, 1990; Silveira, 1971). Superior performance on problems for which work is split over two sessions is taken as evidence for the incubation effect, which is thus operationally defined as any benefit of a break during problem solving.

It is important to emphasize that the definition of incubation adopted in this paper is atheoretical. It does not refer to a given type of processing and in particular does not presuppose unconscious work on the problem. Furthermore, the scope is relatively wide; incubation is taken to be a benefit of *any* break in problem solving relative to continuous work. This leaves open the possibility that, for example, an interruption per se may be beneficial, rather than processing that occurs during the break.

Research has not supported the unconscious work hypothesis; for the most part, investigators have heeded Woodworth and Schlossberg's (1954) advice that this should be put aside until other possibilities have been thoroughly investigated. Of the various theories that have been put forward for incubation, the two that have most support are *fixation* and *opportunistic assimilation.* Both of these ideas have their roots in the Gestalt school of psychology.

The concept of functional fixedness was originally proposed by Duncker (1945) as a source of difficulty in problem solving. When presented with a problem, solvers would be hindered by existing, unhelpful associations with elements of the task. In particular, they would have trouble using tools in a novel way. Duncker argued that an incubation period would allow time for the fixation to recede, leaving the solver to address the problem without such hindrance. More recent work (Smith & Blankenship, 1989; 1991) has demonstrated this effect using word puzzles. If misleading cues are presented with the problem, an incubation period is beneficial, as the disruptive effects of the cues lessen over time.

Maier (1931) investigated priming as a mechanism for incubation. In his famous two-string experiment, he found that by "accidentally" brushing past one of the strings, he could increase the probability that the participant would solve the problem (by setting one of the strings swinging as a pendulum), yet the participant would not see the association between this event and the solution. Priming is a central feature of Seifert et al's (1995) opportunistic assimilation hypothesis. They propose that when an impasse is reached in problem solving, the problem is flagged as an open question in long-term memory. Any relevant information encountered during the incubation period is then

assimilated into the problem representation, facilitated by the stored open question.

In this paper it is argued that these two approaches may be incorporated into a single theory, taking Occam's razor to the facilitatory effect of stored open questions. We propose that incubation is the benefit of a change in context between two attempts at solving a problem. Fixation is simply the unhelpful effect of being in an inappropriate context on the initial attempt; the use of environmental cues is a means of generating a context more conducive to solving the problem at a subsequent attempt.

Under this approach, the context experienced at the second attempt is not necessarily more helpful than the first in solving the problem. The first context may be useful and the problem may be solved straight off. However, for a problem that is not solved initially, a change of context introduces additional cues and potential associations. The incubation period simply allows for this increase in available cues, which may then be brought to bear on the problem.

A recent paper by Dodds, Smith and Ward (2002; see also Smith, Sifonis & Tindell, 1998) directly addressed the use of environmental clues in incubation. During an incubation period, participants were exposed to either the solutions to unsolved problems, or words semantically related to the solutions. Half of the participants were instructed to make use of the clues. Dodds et al. found that only deliberate use of solution words was beneficial. They did not find evidence for related words, or even actual solutions, priming the problem solutions without participants intending to make use of them in solving the problems.

The experiment reported in this paper made use of a stronger context manipulation than that used by Dodds et al. (2002). A single semantic context was established for each of two testing sessions, either animals or fruit and vegetables. The problems then attempted by participants were anagrams, which had solutions drawn from one of the two categories (additional, distracter anagrams were also included). This procedure is a simpler and more powerful manipulation of context than presenting words related to each of a number of different problems.

The paradigm employed compared problems for which work was split over two sessions (incubated) with those worked on in one continuous session (control). The control anagrams were presented in the second session, mixed with incubated anagrams that had already been attempted. A different semantic context was established for each problem solving session.

To illustrate, in the first session a participant might have the "animals" context established, then attempt a mixed set of anagrams, of which those with animal solutions would be easier. In the second session, the "fruit and vegetables" context would be established, then further anagrams attempted, including both previously unsolved and new (control) items. Of these, the anagrams which had fruit or vegetable solutions would be easier. Overall, the participant would be expected to solve more of the anagrams presented in both sessions since these would benefit from both context manipulations.

We hypothesize that incubation is simply a benefit of working in two different contexts, and thus increasing the probability that one of the contexts will prove conducive to solving the problem. Therefore, it is predicted that a set of anagrams presented in two semantic contexts (including items related to both) will have a higher solution rate than a similar set presented in just one context.

The hypothesis of change in context contrasts with Dodds et al's (2002) finding of deliberate use of clues. Therefore, steps were taken to disguise the connection between the context manipulations and the problem solving sessions. Not only were participants not instructed to use clues in solving the anagrams, the clues were presented as a different, unconnected experiment, performed by a different experimenter. This design is intended to preclude, as far as possible, deliberate use of clues.

Method

Participants

Sixty undergraduates of Warwick University took part in this experiment.

Materials

A large pool of anagrams, 5 – 7 letters long, was generated by moving letters of words up to two places from their original positions, e.g. OKMNEY. From these, a set of anagrams of intermediate difficulty was selected by giving eight participants unlimited time to attempt each one. Those that were solved by some, but not all of the participants were retained. The final set of 36 anagrams consisted of 12 whose solutions were animal names, 12 whose solutions were fruit or vegetable names and 12 distracter items. For the purpose of rotating items across conditions (incubated and control), these were divided into three sets, with equal numbers of anagrams from each category in each set. The specific letter rearrangements were matched across anagram set and semantic category.

For the context manipulation, two word searches were created, each 20 x 18 letters in size. One contained the names of 20 animals and the other contained the names of 20 fruit and vegetables, none of which was the solution to any of the anagrams. The words were

written horizontally, vertically and diagonally, in a forwards direction (i.e. left to right; top to bottom).

Design and procedure

A within-subjects design was used, with three factors: Incubated versus control anagrams, time period, and solution category. Incubated anagrams were those for which work was split over two sessions, whereas control anagrams were presented only in the second session. The first and second blocks of fifteen seconds' work on each anagram constituted the two time periods analyzed. The three solution categories were context-relevant, context-irrelevant, and distracters.

Incubated anagrams (24 items consisting of 8 from each category) were each presented for 15 seconds, then those that had not been solved were presented for a further 30 seconds following a context manipulation. Of the second presentation, only the first fifteen seconds' work was included in the analysis. Control anagrams (12 items consisting of 4 from each category) were presented for 30 seconds each in the latter session. This is set out schematically in Table 1.

Table 1: Time spent on each incubated and control anagram in the two sessions

Session	Incubated	Control
Context 1		
Anags 1	1st 15 sec work	
Context 2	INCUBATION PERIOD	
Anags 2 1st 15s	2nd 15 sec work	1st 15 sec work
Anags 2 2nd 15s	3rd 15 sec work Discarded	2nd 15 sec work

Each session of anagram solving was immediately preceded by a context manipulation, such that a different context was created for each session. The manipulation consisted of a word search containing the names of either animals or fruit and vegetables. Anagrams with solutions from the same category as this were termed context relevant, those with solutions from the other category were termed context irrelevant and the remaining anagrams were termed distracters (these were, of course, also context irrelevant).

Participants were not informed of the connection between the context manipulations and the anagrams. They were led to believe that they were taking part in two different experiments, interspersed for convenience. The word searches and anagrams were administered by different experimenters and participants were given a cover story for each task. The four sessions of the experiment are detailed in Table 2.

Table 2: Experimental sessions

Session	Duration	Tasks presented
Context 1	7 min. total	First word search
Anagrams 1	15 sec. per anag.	Incubated anagrams
Context 2	7 min. total	Second word search
Anagrams 2	30 sec. per anag.	Previously unsolved incubated anagrams and control anagrams

For the word search task, the letter grid was presented on paper and participants were given seven minutes to highlight and write down as many words as they could find of the appropriate category (animals or fruit and vegetables). For the anagram task, each anagram was printed on card and presented for 15 or 30 seconds (for the first or second anagram session, respectively). At the end of the experiment, participants were fully debriefed as to the nature of the experiment and the connection between the tasks.

The order of presentation of the anagrams was randomized, with incubated and control anagrams mixed in the second session. The assignment of anagrams to incubation and control conditions was counterbalanced, as was the order of presentation of the word searches.

Results

Performance on the anagram task was measured as the proportion of anagrams solved within each time period. This is summarized in Table 3, which also shows which session of work each measurement is based on.

Table 3: Mean proportion of incubated and control anagrams, of each solution category, solved in each time period. Standard deviations in parentheses.

	Incubated			Control		
Session	CR	CI	D	CR	CI	D
Context 1						
Anags 1	.55 (.21)	.46 (.25)	.39 (.22)			
Context 2						
Anags 2 1st 15s	.50 (.33)	.19 (.23)	.15 (.16)	.57 (.27)	.50 (.29)	.38 (.28)
Anags 2 2nd 15s				.30 (.37)	.21 (.31)	.19 (.29)

CR: context relevant, CI: context irrelevant,
D: Distracter

From Table 3 it can be seen that anagrams presented in a relevant context are more likely to be solved than those presented in an irrelevant context ($t(59) = 4.65$, $p < .0001$, combining incubated and control items and collapsing across time periods). Note that each incubated item was either context relevant in the first session and context irrelevant in the second, or vice versa.

To assess the incubation effect, performance on incubated anagrams in the second session (i.e. after the break) should be compared with performance on control anagrams in the equivalent time period (the latter 15s of work). However, this is complicated by the effect of practice, since participants tend to solve anagrams more quickly in the second session. This produces an item selection bias in the control anagrams, in that most of the easier items are solved in the first fifteen seconds, leaving only the more difficult items to be attempted in the latter fifteen seconds. This would tend to produce an apparent incubation effect as an artifact, and therefore must be accounted for if incubation is to be assessed. Ideally, we need to know what the incubation effect would be if there were no practice effect.

This can be done if incubation is measured as the difference in performance between incubated and control items in the latter fifteen seconds of work, and practice is measured as the difference in performance between incubated and control items in the first fifteen seconds of work. A regression analysis can then be conducted, regressing incubation on practice. The calculated intercept is an estimate of the incubation effect when no practice effect is found.

The above analysis was conducted twice; for the distracter items and for items from the other two categories. For the distracter items, the intercept was not significantly different from zero (intercept = -0.05, $t(53) = -1.2$, $p = .23$)[1]. For items subject to the context manipulation (collapsing across context relevant and context irrelevant items), the intercept was significantly greater than zero (intercept = 0.13, $t(53) = 2.7$, $p = .009$). Therefore, after partialling out the effect of practice, the proportion of incubated items solved after a break is estimated to be 0.13 higher than the corresponding proportion of control items solved.

The difference in incubation effect for distracters versus context-manipulated items was assessed by taking the difference between the incubation measurements for the two sets of items for each participant and regressing this difference score on both the practice scores (for distracter and context-manipulated items). The resulting intercept was significantly greater than zero (intercept = 0.19, $t(52) = 2.7$, $p = .01$), indicating that the incubation effect for context manipulated anagrams was significantly greater than that for distracter anagrams.

[1] Five participants were excluded from these analyses on account of missing data. If all anagrams in a given category were solved in the first 15s none remained to be attempted in the latter 15s.

Discussion

The incubation effect was demonstrated for problems that had been subject to a context manipulation, but not for those that had not. A direct comparison between anagrams that had been presented in a relevant context with equivalent anagrams presented in an irrelevant context showed clearly that the context manipulation was effective.

The benefit of incidentally presented hints, as found in this experiment, may be similar to that found by Kokinov, Hadjiilieva and Yoveva (1997). They presented a hint, in the form of a diagram, simultaneously with the problem attempted by participants. They found that the hint was most valuable when presented as part of another problem, not attempted by the participants and unconnected with the task they were instructed to work on. If the same hint was presented as a clue, with explicit instructions to use it, performance was actually worse than in a no-hint condition.

That incidental hints or context manipulations should be helpful in some cases, whereas only deliberate use of direct clues is helpful in other cases (such as Dodds et al., 2002), poses an interesting question. There is not sufficient evidence available at present to resolve this question, but we may speculate on a plausible explanation. Where the hint provides a single concept, such as the structure conveyed in a diagram, or a category label, this may influence the problem solver without requiring deliberate attention, or even awareness. Conversely, more complex information, such as multiple concepts related to a number of different problems, cannot prime solutions effectively, but require attention in order to be utilized.

This paper has demonstrated the effectiveness of a context manipulation in producing incubation. Whilst this does not rule out the possibility of other mechanisms, it implies that the incubation effect may be no more than the benefit of a change in context. Working on a problem in two different contexts simply extends the range of contextual cues available for use in solving that problem.

Yaniv, Meyer and Davidson (1995) argued for the role of a special memory representation of the unsolved problem. They proposed that this would facilitate the formation of associations between the unsolved problem and relevant information encountered incidentally. Their experiments in the area of memory retrieval showed that the solution presented prior to attempting a problem would be more valuable if the problem had been seen before, provided that the delay

between the first attempt at the problem and the presentation of the solution was sufficiently short. The restricted conditions required for this facilitation (presentation of the exact solution soon after an initial attempt) and the lack of convincing evidence for this effect in problem solving (as distinct from memory retrieval) lead us to question the value of this aspect of their theory, as it relates to incubation. A more parsimonious account of incubation is the benefit attempting the problem in multiple contexts, as demonstrated in this paper.

Acknowledgments

We would like to thank Elizabeth Allen and Katherine Wilmshurst, who conducted the experiment reported here as their undergraduate research project.

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