Japanese Psychological Research
THE JAPANESE PSYCHOLOGICAL ASSOCIATION

Japanese Psychological Research
2019, Volume 61, No. 2, 94–106
Special issue: Implicit Cognition

doi: 10.1111/jpr.12237

Positive and Negative Affects Facilitate Insight Problem-Solving in Different Ways: A Study with Implicit Hints[1,2]

RYO ORITA[3,*] and MASASI HATTORI *Ritsumeikan University*

Abstract: This study investigates the influence of affective states on the use of implicit hints when solving insight problems. To examine this, two experiments were conducted, both with Duncker's (1945) radiation problem as an insight problem. When primed with a hint, positive affect inhibited the number of incorrect solutions generated in Experiment 1 and increased the number of correct solutions in Experiment 2. In contrast, negative affect enhanced the participants' performance regardless of the presence of hints across the two experiments. These results indicate that positive and negative affect facilitate insight problem-solving in different ways. It seems that positive affect implicitly prompts the acceptance of cues and broadens people's search of a problem space, and negative affect encourages people to intensively focus on solving the insight task. The results suggest a resolution of a long-standing debate on the effectiveness of positive versus negative affect in solving a problem.

Key words: implicit cognition, affect, insight problem-solving.

Every day, people address a variety of problems, from trivial ones encountered in daily life (e.g., finding a shortcut) to serious business-related challenges (e.g., reorganizing the company). A problem may seem to be difficult to solve for someone in some cases, but the same problem can be considered trivial for another person or even for the same person in another context. Obviously, there are many factors, internal and external, that affect the process of problem-solving; in particular, affect (e.g., happiness or sadness) is widely acknowledged as one of the most important internal factors. Numerous studies have investigated the influence that affective states have on insight problem-solving or creativity (for a review of this, see Baas, De Dreu, & Nijstad, 2008; Jovanovic, Meinel, Schrödel, & Voigt, 2016); the results of these studies, however, have inconsistencies in terms of the type of affect that facilitates insight.

Some studies have reported that positive affect has a positive influence on problem-solving. For example, Estrada, Yong, and Isen (1994) and Isen, Daubman, and Nowicki (1987) found that induced positive affect promotes insight problem-solving. De Dreu, Baas, and Nijstad (2008) also found that positive

*Correspondence concerning this article should be sent to: Ryo Orita, Faculty of Human Science, University of East Asia, Ichinomiyagakuen-cho, Shimonoseki, Yamaguchi 751-0807, Japan. (E-mail: r-orita@toua-u.ac.jp)

[1]This research was supported by JSPS KAKENHI (JP15H02717 and JP17K18237).

[2]A part of this research was presented at the 36th Annual Meeting of the Cognitive Science Society and the 31st Annual Meeting of the Japanese Cognitive Science Society.

[3]Present affiliation of first author is Faculty of Human Sciences, University of East Asia, Shimonoseki, Japan.

affect facilitates creativity through enhancing cognitive flexibility. According to Schwarz and Clore (1996), positive affect leads individuals to perceive themselves to be in a safe environment, which allows them to freely explore novel pathways and new possibilities. Such inclusive thinking can be realized through applying diffused attentional focus in conjunction with positive affect (Rowe, Hirsh, Anderson, & Smith, 2007).

In contrast, another body of research has shown that negative affect has facilitative effects on insight and creativity (George & Zhou, 2002; Kaufmann & Vosburg, 1997, 2002). De Dreu et al. (2008) showed that negative affect enhances performance in insight tasks through improving persistence. This is because negative affect signals that the individual's current state of affairs is problematic (Schwarz & Clore, 1996), and that in-depth and elaborative thinking is required to resolve the situation (Dietrich, 2004). Such enhanced persistence is based on high "cognitive control" (Tidikis, Ash, & Collier, 2017).

This inconsistency between positive and negative affect suggests that the two kinds of affect facilitate insight problem-solving through different mechanisms. As a result, the influence of positive and negative affect may show diverse patterns depending on problem situations and solvers' states. "Dual-process models" of insight problem-solving (Cassotti, Agogué, Camarda, Houdé, & Borst, 2016; Gilhooly & Murphy, 2005) suppose that both Type 1 (intuitive and implicit) and Type 2 (effortful and explicit) processes are used to complete a task; the former is based on an unconscious associative learning mechanism that is independent of cognitive control, while the latter involves conscious and deliberative thought that heavily depends on cognitive control (Robertson, 2017). Many previous studies have shown the obstructive influence that positive affect has and the facilitative influence that negative affect has on cognitive control (Basso, Schefft, Ris, & Dember, 1996; Phillips, Bull, Adams, & Fraser, 2002; for a review, see Mitchel & Phillips, 2007). These results suggest that positive affect is related to implicit and flexible thought whereas negative affect is associated with explicit and elaborative thought. Therefore, the nature of implicit and explicit thought processes can be a clue for revealing the mechanism of positive and negative affect in problem-solving.

Implicit thought in problem-solving can be probed by priming as impressively demonstrated by some recent studies, such as Hattori, Sloman, and Orita (2013) and Suzuki and Fukuda (2013), who showed the facilitative effect of unrecognized (i.e., subliminal) hints. Implicit hints are pieces of information that assist the solving of a task even though the solvers cannot consciously see the hints or realize their relevance to the problem. The effect of implicit hints has actually been suggested by some previous studies, including Moss, Kotovsky, and Cagan (2007), who found that unattended (i.e., supraliminal) cues presented in ostensibly unrelated tasks produce a priming effect and aid problem-solving. The effect, however, was not fully conclusive, as participants might just have forgotten the hint that was visible in fact. Studies with subliminal stimulation established the effect of implicit information in higher-order cognition, such as problem-solving. In insight problem-solving, people often suddenly realize a solution (Sternberg & Davidson, 1995) but cannot correctly introspect the processes that led them to this insight (Metcalfe, 1986); hence, it is impossible to clarify the processes involved based on introspection. In contrast, hint priming is an effective method for detecting the implicit processes of insight (Hattori et al., 2013).

Implicit hints can enhance the solving performance of individuals who are in a positive affective state, but this may not be the case for those in a negative affective state. Schwarz and Skurnik (2003) argued that the affective states influence whether people spontaneously adopt a knowledge-driven or a data-driven strategy of information processing and hence influence how they represent a problem. Friedman and Förster (2000) observed that the bodily approach feedback increased the performance on a verbal analogy task. The approach actions may be relevant to the positive affect (Förster & Strack, 1997), and this good affective state may facilitate the analogical transfer in insight problem-solving.

In another line of study, implicit hints have been found to increase the performance of solvers who have low cognitive control. For example, Kim, Hasher, and Zacks (2007) showed that supraliminal priming of hints increases the performance of older adults attempting to negotiate remote associative tasks, but has no such effect for younger adults. Consequently, they argued that age-related decline of cognitive control is responsible for the enhancing effect of implicit hints. Nishida, Orita, Hattori, Custoldi, and Macchi (2018) also showed that high inhibitory control hampers the application of subliminally primed hints. They argued that low cognitive control broadens solvers' attentional focus, and that this diffused attention may facilitate the acceptance of implicit hints from the environment. These results, combined with the results of Rowe et al. (2007), who found that the diffused attentional control caused by induced positive affect increases performance in insight tasks, suggest that implicit hints are more effective in a positive affective state.

Our hypothesis is that solvers with positive affect can obtain more benefits from implicit hints when performing insight problem-solving. This possibility has actually been tested once by Jaušovec (1989), who conducted experiments involving supraliminal priming of analogical hints in insight and non-insight tasks. However, he did not identify the enhancing influence that positive affect has on the use of hints in insight problem-solving. This might be because it was not assured, in his experiment, that participants did not recognize the role of analogical base as the hint of the problem; some participants may have consciously and strategically used the hint to solve the problem. If this happens, the influence of affect, which is implicit in nature, might be overshadowed. Therefore, in this study, we re-examined the effects using an implicit hint. We used the method of stimulation with both a hint that is supraliminal (i.e., recognizable but unidentifiable as a hint, Experiment 1) and a hint that is subliminal (i.e., not recognizable, Experiment 2). We used these two different methods, which can actually have a similar effect as Bargh and Chartrand (2000) have suggested, to ensure that the effect is due to the implicit nature of the process regardless of the difference of stimulation.

Experiment 1

For Experiment 1, we examined the influence of solvers' affective states on their use of implicit analogical hints when engaging in insight problem-solving. Analogical problem-solving refers to solving the target problem by applying knowledge relating to solutions to other problems (i.e., bases) that have an analogous structure to that of the target issue. Contrary to Gick and Holyoak (1980), who suggested that a hint must be acknowledged as a hint to have its effect, Hattori et al. (2013) claimed that a subliminal hint can function as a primer. However, Hattori et al.'s findings also differ from those of the aforementioned Jaušovec (1989), who did not observe hints having any influence on individuals in positive affective states. Considering this, for this experiment we chose to use a supraliminal primer to detect the influence of affect.

Method

Participants and experimental design. For Experiment 1, 188 undergraduate students (119 females and 69 males; age: 19–68 years, M = 20.7 years, SD = 3.9 years) enrolled in Ritsumeikan University participated. The experiment was conducted in a classroom, and all participants were present at the same time. Each respondent was randomly assigned to one of six conditions in a 3 (affect induction: positive, neutral, or negative) × 2 (base: hint or misleader) between-participants design.

Analogical information. Duncker's (1945) radiation problem was used as an insight task. This problem places the participants in the role of a doctor who is treating a cancer patient. The cancer is inoperable, but it is possible to destroy the malignant tumor using a ray. To effectively destroy the tumor, the ray must be set at a sufficiently high intensity; however, at such an intensity, healthy tissue is also destroyed. If the ray is set to a lower intensity, it will damage neither the healthy tissue nor the tumor. Thus, the participants were asked to determine a procedure by which the ray could be used to destroy the tumor without damaging the healthy tissue. The solution to this problem is to simultaneously direct multiple low-intensity rays toward the tumor from different directions, which is called a *dispersion-and-concentration solution.*

Two base stories were used. Both were stimuli used in Gick and Holyoak's (1980) study, and these were translated into Japanese for the participants. One was the "attack-dispersion" story as a "hint." This story features a general who wishes to capture a fortress located in the center of a country. There are many roads leading to the fortress; however, all have been mined. Thus, while small groups of men can travel along the roads safely, large groups would detonate the mines. Consequently, the general divides his army into small groups, sends each group to a different road, and has the groups converge simultaneously on the fortress. Since the analogical solution to the radiation problem is dispersion-and-concentration, Gick and Holyoak (1980) used this base story as a hint.

The other base story was the "tunnel" story as a "misleader." In this story, which features the same setting as the attack-dispersion story, the general digs an underground tunnel and sends his army through it to the fortress. An analogical solution to the radiation problem is to operate to expose the tumor to the rays, or to insert a tube through the stomach wall and send rays through it to the tumor ("operation" solution); in Duncker's (1945) experiment, many participants (40%) gave such a solution. However, the operation solution conflicts with the constraints imposed in the radiation problem; thus, the tunnel story is an inappropriate, misleading base.

Procedure. Before starting on experimental tasks, participants were told that they might be offended during the tasks. All participants signed informed consent and were debriefed after all tasks were completed.

Experiment 1 consisted of three tasks, and participants were told that these tasks had no relation to each other. Further, these tasks were presented on individual booklets featuring different formats and fonts. The order of these tasks was the same as the experiment by Jaušovec (1989). The first was a story-evaluation task in which the base stories were manipulated. Participants were presented with three stories and were given 8 min to note their degree of comprehension of and interest in each; the second of these three stories was the base story. Here, half of the participants received the attack-dispersion story (i.e., a hint condition), while the other half received the tunnel story (i.e., a misleader condition). The contents of the first and third stories had no relation to the radiation problem.

In the second task, participants' affective states were manipulated. This manipulation was conducted using an autobiographical recollection procedure proposed by Baker and Guttfreund (1993). Specifically, participants were asked to think of two happy events (i.e., a "positive" condition) or two sad events (i.e., a "negative" condition) they had experienced in their lives, and to write detailed descriptions of these. Meanwhile, participants in the "neutral" condition were asked to recall and write as many items as they could that related to the categories of fish, flower, and furniture. The time limit for this second task was 10 min.

In the third task, participants were given 8 min to solve the radiation problem, and were allowed to freely write their solutions. They were only presented with information concerning the problem. No graphical representation of the problem was included.

After this, the affect-induction manipulation was checked. It was not checked immediately after the affect induction to ensure that the affect-induction effect was sustained during the problem-solving task (Stangor, 2014). Participants were asked to indicate their current feelings by responding to 24 items from the General Affect Scale (GAS; Ogawa, Monchi, Kikuya, & Suzuki, 2000). The GAS consists of three 8-item subscales: Positive Affect (PA), Negative Affect (NA), and Calmness (CA). Participants scored all of these items using a four-point Likert scale ranging from 1 (*not at all*) to 4 (*extremely*).

Finally, participants were asked whether they had encountered the radiation problem before, to which they answered *yes*, *no*, or *I am not sure.* They were then asked whether they thought that the story about the army general contained a hint for solving the radiation problem, which they responded to by choosing *yes* or *no.*

Results

Of the 188 participants, 23 reported that they had encountered the radiation problem before, four correctly identified the second story presented in the evaluation task as the hint, and three returned incomplete data. The data from all of these participants were excluded from analysis.

Manipulation check. The GAS showed high internal consistency for PA ($\alpha = .94$), NA ($\alpha = .87$), and CA ($\alpha = .90$). Scores for these items were averaged to form a single index for each affect factor (Table 1). The three scores were then analyzed using a two-way analysis of variance (ANOVA) featuring affect induction (positive, negative, and neutral) and the base stories (hint and misleading). For the PA score, the analysis indicated that affect induction had a significant main effect, $F(2, 152) = 51.40$, $p < .001$, $\eta_p^2 = .40$. Meanwhile, a subsequent multiple comparison test using the Bonferroni method revealed that all comparisons were significant, *t*s > 5.10, *p*s < .001. Thus, the induction of positive affect was successful. In regard to the NA score, the ANOVA showed no significant effects, *F*s < 1.0, while for the CA score the main effect of affect induction was significant, $F(2, 152) = 7.80$, $p < .001$, $\eta_p^2 = .08$; the CA score in the negative condition was lower than that in the neutral condition, $t = 3.93$, $p < .001$, and marginally lower than that in the positive condition, $t = 2.37$, $p = .06$. Thus, participants in the negative condition were induced into less positive and less calm affective states.

Table 1 Mean affect ratings (GAS) of each affect condition in Experiment 1

Induced Affect	Scores of GAS PA	NA	CA
Positive	2.64 (0.11)	1.53 (0.09)	2.10 (0.10)
Neutral	1.99 (0.09)	1.71 (0.07)	2.34 (0.09)
Negative	1.30 (0.07)	1.72 (0.10)	1.80 (0.10)

Note. Numbers in parentheses represent standard error.

Analogy. Participants' responses to the radiation problem were categorized into three groups: dispersion-and-concentration, operation, and other. Overall, the percentage of those who suggested the dispersion-and-concentration solution was very low (3.8%). A binary logistic regression analysis using the Affect Induction (3) × Base Stories (2) factorial design showed no significant effects, $\chi^2 < 1.0$.

Figure 1 shows the rate of the operation solution, a typical incorrect answer. In the misleader condition, however, it is not only frequent as a base rate but is also supposed to be misled by the false base (i.e., tunnel) story. Binary logistic regression analysis showed that affect induction had a significant main effect, Wald's $\chi^2(2) = 6.89$, $p = .03$; meanwhile, the multiple

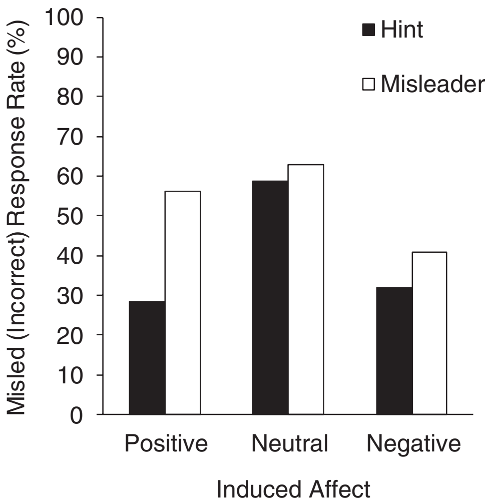

Figure 1 Response rate of misled (i.e., operation) solution in Experiment 1 as a function of induced affect and primed base stories.

comparison test conducted using the Bonferroni method revealed that the percentage of participants who gave the operation solution was lower in the negative condition (36.7%) than in the neutral condition (60.7%), $z = 2.47$, $p = .04$. The main effects of the base, $\chi^2(2) = 2.95$, $p = .09$, and the interaction effect, $\chi^2(2) = 1.58$, $p = .45$, were not significant; however, a planned comparison using the χ^2 test revealed that, for the positive condition only, the percentage who gave the operation solution was lower in the hint condition (28.6%) than in the misleading condition (56.3%), $\chi^2(1) = 3.92$, $p = .04$, $\phi = .33$.

Discussion

The analysis of the correct solution (i.e., dispersion-and-concentration) to the radiation problem showed that the analogical hint and the induced affective states had no effect. This may be because of the very low solution rate (3.8%), which is consistent with the result of Duncker's (1945) experiment (4.8%). In the analysis of the incorrect solution (i.e., operation), however, it was found that very few participants induced to positive affect gave this solution when they were implicitly presented with the attack-dispersion base story as a hint. This low level of operation responses may mean that under these conditions individuals can refrain from choosing a solution that many others select erroneously. This result indicates that positive affect facilitates the spontaneous use of implicit hints and helps solvers overcome fixation on false solutions. In Experiment 1, the affect induction procedure was conducted after the presentation of analogical bases. Thus, the positive affect influenced only the use of base during the problem-solving stage, not the initial processing of it.

Another interpretation of this significant effect of implicit base in the positive affect participants might be that the induced positive affect facilitates the use of the inappropriate base and leads to the incorrect solution. This interpretation, however, is not supported by the comparison of the incorrect solution rate between the positive and neutral conditions. Figure 1 shows that when the misleader was presented, the incorrect solution rate of positive affect participants was similar to that of the neutral affect participants. This result indicated that the induced positive affect did not lead to the incorrect solution suggested by the misleader. People often lapse into a false solution of the same kind in solving an insight problem, and this can happen no matter whether they are vulnerable to a piece of misleading information in the environment. This is perhaps because they can all easily retrieve a piece of similar information from their own memory.

On the other hand, induction to negative affect decreased the number of inappropriate operation solutions, regardless of the base stories given in the task. This result indicates that the beneficial influence of negative affect on insight problem-solving may not be dependent on the use of implicit hints. It should be noted, however, that the induction of negative affect employed in this experiment was not completely effective. The NA score of the participants in the negative condition did not differ from those in the positive and neutral conditions. Moreover, the CA score of the participants in the negative condition was lower than that of those in the positive and neutral conditions. These results suggest that the cause of facilitative influence observed in the negative condition might be their high arousal state, not their negative affective state. Therefore, the influence of negative affect induction must still be verified.

Experiment 2

The results of Experiment 1 suggest that affective states alter the way externally valid cues are incorporated into problem-solving. Although this process of control seems to work without consciousness and to be independent of cognitive control, as long as the participants are able to consciously see the hint, it is difficult to deny the involvement of consciousness. With this concern, in the second experiment, we adopted a technique of subliminal priming, wherein participants do not consciously see the hint, in order to make clearer the unconscious nature of the process of assimilation of a valid cue into problem-solving influenced by affect status. In

Experiment 2, participants were first induced into three different affective states as in Experiment 1, and half of them were then subliminally primed with a hint figure before solving the target problem.

Another issue of Experiment 1 was the low rate of the correct solution, which might have caused the non-significant effect of the implicit hint. Therefore, in this experiment, the procedure for conducting the radiation problem was changed to decrease the difficulty of the task.

As mentioned in the Discussion section of Experiment 1, we thought that showing a misleader may not be an appropriate method to detect an implicit information effect if solvers lapsed into a particular kind of incorrect solution no matter whether the misleader existed or not. Therefore, we omitted misleader conditions in this experiment, and instead incorporated a control condition where no informative hint was presented. This is expected to provide the baseline of the solution rate and to enable us to estimate the effect size of the implicit hint on the solvers' performance.

Method

Participants and experimental design. For Experiment 2, 129 undergraduate students (68 females and 61 males; age: 18–29 years, M = 20.8 years, SD = 1.3 years) from Ritsumeikan University participated solely or as a group of two to five. They were randomly assigned to one of six conditions in a 3 (affect induction: positive, neutral, or negative) × 2 (priming: hint or no-hint) between-participants design.

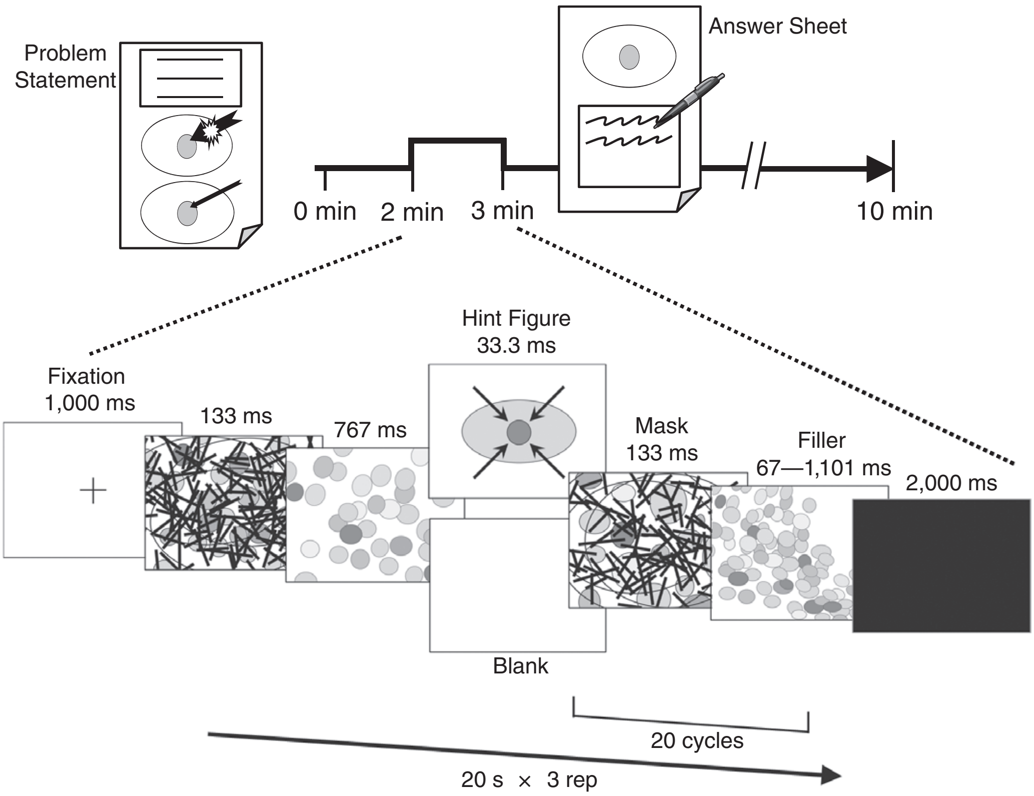

Figure 2 Schematic description of the insight task and a sequence of frames, including the implicit hint stimuli in Experiment 2. The actual duration of the presentation of each image was checked by counting the number of frames (600 fps) using a high-speed camera (Casio EX-F1).

Stimulus. The hint stimulus in the hint condition was similar to that used by Hattori et al. (2013, Experiment 1). The figural hint image was presented as part of a 60-s movie, which was composed using one hint image (exposed 33 ms × 60 times), two mask images, three filler images, and one fixation image (Figure 2). The movie was presented on a 21-in. display (1,280 × 1,024 pixels) using a personal computer (Dell Optiplex 960, Windows 7). In the no-hint condition, a movie in which the hint image was replaced by a blank was used.

Procedure. Experiment 2 consisted of two tasks. Participants were told that these tasks were irrelevant to each other. The first task concerned autobiographical recollection, in which participants' affects were manipulated using the same procedure as that used in Experiment 1.

The second task was to solve the radiation problem. A visual image of the radiation problem was presented with the problem statement, and a similar image was also included in the answer sheet (Figure 2). The purpose of these changes from Experiment 1 was to facilitate the formation of problem representation and to increase the percentage of correct answers.

In the study of Hattori et al. (2013), the hint image was primed during the problem-solving task. Using this method, they showed a robust influence of hint priming. As the stimulus intensity of subliminal priming was supposed to be lower than that of supraliminal priming (i.e., the presentation of analogical base), the hint was primed not before the affect induction but during the radiation task in Experiment 2. Two minutes after the participants commenced the task, they were shown "an irrelevant movie, to provide a break from the puzzle" (the hint stimulus) for 1 min. They were given a total of 10 min to complete the radiation problem, comprising the initial 2-min trial period, the 1-min exposure to the movie, and the second 7-min trial period (Figure 2). When participants finished, they informed an experimenter. Then, for each participant, the experimenter recorded the time that had elapsed since the commencement of the task.

To conduct a manipulation check of affect induction, the short-form of the Multiple Mood Scale (MMS; Terasaki, Kishimoto, & Koga, 1992) was used; the MMS can detect individuals' affective states more multilaterally than the GAS. This scale consists of eight 5-item subscales: three concerning PA (Friendliness, Well-being, and Liveliness), three concerning NA (Hostility, Depression, and Boredom), and two concerning CA (Surprise and Concentration). Participants scored these items using a 4-point Likert scale ranging from 1 (*not at all*) to 4 (*extremely*).

Finally, participants were asked if they had previously encountered the radiation problem before, using the same question as in Experiment 1. Furthermore, participants were presented with four figures, and asked to choose the one that they thought had been shown in the irrelevant movie, showing their certainty using a confidence rating.

Results and Discussion

Of the 129 participants, 14 reported that they had encountered the radiation problem before, 10 in the hint condition correctly identified the hint image, and nine completed the radiation problem before seeing the movie. Data from all of these participants were excluded from the analysis.

Manipulation check. Scores for each of the eight MMS subscales were calculated and the internal consistency for PA ($\alpha = .76$) and NA ($\alpha = .70$) was found to be satisfactory, so they were averaged to form a single index for each affect factor. However, the internal consistency between the two CA subscales was low ($\alpha = .47$); consequently, these subscales were analyzed separately. Their mean scores are shown in Table 2.

A two-way ANOVA featuring affect induction (positive, negative, and neutral) and priming (hint and no-hint) showed that affect induction only had significant main effects on PA score, $F(2, 90) = 107.9$, $p < .001$, $\eta_p^2 = .71$, and NA score, $F(2, 90) = 42.7$, $p < .001$, $\eta_p^2 = .49$. A subsequent multiple comparison test

Table 2 Mean affect ratings (MMS) of each affect condition in Experiment 2

	Scores of MMS			
Induced Affect	PA	NA	Surprise	Concentration
Positive	2.71 (0.10)	1.35 (0.07)	1.37 (0.10)	2.04 (0.12)
Neutral	1.61 (0.06)	1.79 (0.08)	1.63 (0.11)	2.11 (0.12)
Negative	1.34 (0.03)	2.23 (0.05)	1.52 (0.08)	2.06 (0.08)

Note. Numbers in parentheses represent standard error.

using the Bonferroni method revealed that all comparisons were significant in regard to both the PA and NA scores, ts > 2.75, ps < .02. Thus, the induction of positive and negative affects was successful. For scores concerning surprise and concentration, the ANOVA showed no significant effects, Fs < 1.0.

The effect of the subliminal hint. Participants' responses to the radiation problem were categorized into correct solution (i.e., dispersion-and-concentration), and other. The solution rate in Experiment 2 (52.1%) was higher than that in Experiment 1 as expected. This may be because the presentation of a visual image of the radiation problem facilitated the formation of problem representation.

It was presumed that the hint priming increased the percentage of participants who identified the correct solution and/or reduced the time required to determine the solution; to examine this probability, we conducted a survival analysis, which reveals the effect of independent variables both on the incidence rate of a specific event (i.e., find the solution) and on the duration time until the event happened. For each condition in the Induced Affects (3) × Priming Stimulus (2) design, the percentage of correct solutions as a function of elapsed time was estimated based on the Kaplan–Meier method. Thirty-two participants were treated as "censoring" because they finished the task with the false response (e.g., operation solution). Estimated curves are shown in Figure 3; these curves were compared using a parametric test, assuming log-normal distribution.

The survival analysis showed a significant main effect for affect induction, Wald's $\chi^2(2) = 19.41$, $p < .001$, and a marginally significant interaction effect, $\chi^2(2) = 5.38$, $p = .07$. Next, a test of the simple effects of priming showed that, in the positive condition, hint priming facilitated performance, $\chi^2(1) = 8.18$, $p = .004$; however, in the neutral and negative conditions, the simple effects of priming were

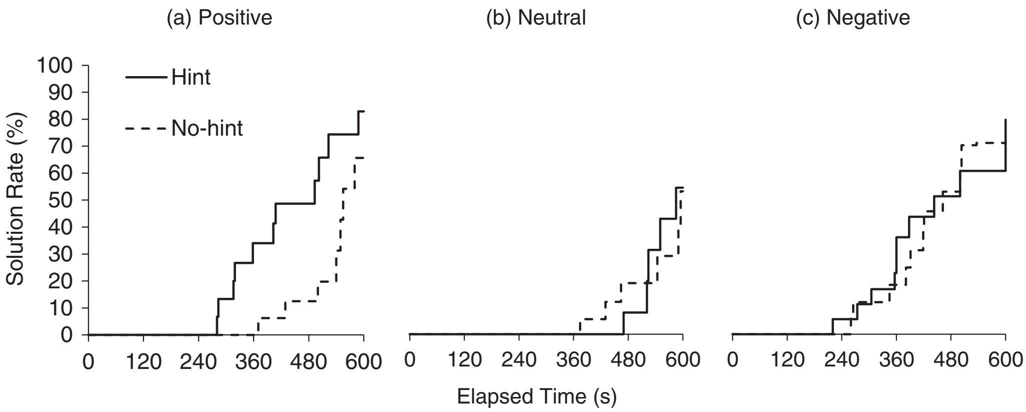

Figure 3 Cumulative solution rate as a function of elapsed time by experimental condition of affect and priming in Experiment 2.

not significant, $\chi^2 < 1.0$. Meanwhile, the simple effects of affect induction were determined to be significant in both the hint and no-hint conditions, $\chi^2(2) = 13.97$, $p < .001$; $\chi^2(2) = 10.05$, $p = .007$. Furthermore, the multiple comparison conducted using the Bonferroni method showed that, in the hint condition, the performance of the positive condition was better than that of the neutral condition, $z = 3.10$, $p = .006$, while the performance of the negative condition, on the other hand, was better than that of the neutral condition in the hint condition, $z = 3.55$, $p = .001$, and better than those of the neutral and positive conditions in the no-hint condition, $z\text{s} > 2.66$, $p\text{s} < .03$.

In sum, Experiment 2 demonstrated that the beneficial influences of positive and negative affect manifest in different ways. Positive affect facilitated insight problem-solving by encouraging the use of the implicit hint; in contrast, the negative affect did so without depending on the hint. These results were observed when the induction of positive and negative affect was successful, hence, the findings are clearer than those of Experiment 1.

General Discussion

The results of the two experiments indicate that positive affect facilitates the use of implicit hints in insight problem-solving. In Experiment 1, supraliminal priming with positive affect decreased the inappropriate solution that many people usually work out and easily conceive. This result suggests that positive affect facilitates the use of knowledge concerning the problem structure acquired from a primed base, mapping between such knowledge and the target problem, and a reduction in fixation on false solutions. In Experiment 2, subliminal priming with positive affect increased the correct solution. Positive affect broadens attentional focus (Rowe et al., 2007), and the diffused attention seems to permit the acceptance of beneficial cues from the environment. This can help utilize the cues in associative thinking conducted when searching for the solution for solving the problem.

On the other hand, across the two experiments, negative affect improved performance without the presence of implicit hints. In Experiment 1, negative affect decreased the unsatisfactory solution, regardless of the prime. Similarly, in Experiment 2, negative affect increased the correct solution not only in the hint condition but also in the no-hint condition. These results suggest that the facilitating influence of negative affect on insight problem-solving manifests without dependence on a primed hint.

The distinct pattern of the implicit hint's effects on positive and negative affect suggests that these affective states facilitate insight problem-solving in different ways. Positive affect may be related to implicit processing and flexible thought, meaning solvers can execute an associative search of the solution based on the environmental cues. Meanwhile, negative affect may be associated with explicit processing and elaborative thought, which enable solvers to execute persistent and in-depth searches for solutions (Dietrich, 2004); in this elaborative processing, the implicit hint may be out of attentional focus, and consequently may have no or little influence.

The results of Experiment 1 were inconsistent with those of a previous study. Jaušovec (1989) found that induced positive or negative affect had no influence on the use of an analogical base presented verbally in regard to solving the radiation problem. In the Introduction section, we mentioned the possibility of an overshadowing effect of consciousness. Another reason may be the structure of the radiation problem. Although this problem is classified as ill-defined, the determining criteria for whether a given solution is correct are well-defined. Jaušovec (1989) argued that this type of problem does not involve intuitive and associative thinking and, thus, is not vulnerable to the effect of an analogical base. This argument was not supported by our results from Experiment 1, in which positive affect facilitated a reduction in fixation to incorrect solutions when the analogical hint was presented; the response rate of incorrect solutions was not analyzed in Jaušovec's (1989) study. Overcoming fixation is accompanied by associative thinking (Gilhooly & Murphy, 2005) and by changing the presentation of the problem (Batchelder & Alexander, 2012). Thus, searching for a well-defined solution to the radiation problem may involve an associative process in which positive affect broadens the search area of the solution through the use of the hint.

The difference between positive and negative affect in terms of the use of an implicit hint may be related to the solvers' attentional inhibition. The use of an implicit hint is inhibited when solvers' attentional inhibition is high (Nishida et al., 2018). Furthermore, attentional control is influenced by affective states (Mitchel & Phillips, 2007). These findings suggest that the influence of affective states on the use of implicit hints may be mediated by changes in attentional control. Future research should examine this possibility to clarify the relationships between affect and insight problem-solving.

Another issue for future research is arousal. De Dreu et al. (2008) and Tidikis et al. (2017) distinguished between high and low arousals in each of the positive and negative affect states (e.g., happiness vs. calmness, and anger vs. sadness) and found that the level of arousal altered the influence of affect. It may be necessary to classify the solvers' affective states in more detail and investigate their influence on the use of implicit information in problem-solving.

Finally, let us note some limitations and future directions of this study. First, only one insight problem task (i.e., the radiation problem) was used in this study. It was good for comparing the results with those of Jaušovec (1989), but the findings should be tested with other tasks, such as the Remote Associates Task (Mednick, 1962; for the Japanese version, see Orita, Hattori, & Nishida, 2018). Second, the autobiographical recollection procedure used for affect induction failed to induce the negative affect in Experiment 1. It might be worth testing other methods for affect induction (e.g., the film presentation by Isen et al., 1987) in future research. Third, the procedures in Experiment 1 and 2 were not exactly the same because of a methodological constraint, and the results were, albeit consistent, not exactly the same either. A hint was primed *before* the affect induction in Experiment 1, but it was *after* in Experiment 2. As a result, priming had no effect on the solution rate in Experiment 1, but a significant effect in Experiment 2. Therefore, the relationship between task order and the effect of priming (in relation to affective states) is not clear for now. We leave this question open, and it must be clarified by future research that reveals the nature of complicated interactions between affect and information use.

Conflict of Interest

The authors have no conflicts of interest directly relevant to the content of this article.

References

Baas, M., De Dreu, C. K., & Nijstad, B. A. (2008). A meta-analysis of 25 years of mood-creativity research: Hedonic tone, activation, or regulatory focus? *Psychological Bulletin*, *134*, 779–806.

Baker, R. C., & Guttfreund, D. G. (1993). The effects of written autobiographical recollection induction procedures on mood. *Journal of Clinical Psychology*, *49*, 563–568.

Bargh, J. A., & Chartrand, T. L. (2000). Studying the mind in the middle: A practical guide to priming and automaticity research. In H. T. Reis & C. M. Judd (Eds.), *Handbook of research methods in social and personality psychology* (pp. 253–285). New York, NY: Cambridge University Press.

Basso, M. R., Schefft, B. K., Ris, M. D., & Dember, W. (1996). Mood and global-local visual processing. *Journal of the International Neuropsychological Society*, *2*, 249–255.

Batchelder, W. H., & Alexander, G. E. (2012). Insight problem solving: A critical examination of the possibility of formal theory. *Journal of Problem Solving*, *5*, 56–100.

Cassotti, M., Agogué, M., Camarda, A., Houdé, O., & Borst, G. (2016). Inhibitory control as a core process of creative problem solving and ideas generation from childhood to adulthood. *New Directions for Child and Adolescent Development*, *2016*, 61–72.

De Dreu, C. K. W., Baas, M., & Nijstad, B. A. (2008). Hedonic tone and activation level in the mood-creativity link: Toward a dual pathway to creativity model. *Journal of Personality and Social Psychology*, *94*, 739–756.

Dietrich, A. (2004). The cognitive neuroscience of creativity. *Psychonomic Bulletin & Review*, *11*, 1011–1026.

Duncker, K. (1945). On problem solving. *Psychological Monographs*, *58*, i–113.

Estrada, C. A., Yong, M. J., & Isen, A. M. (1994). Positive affect improves creative problem solving and influences reported source of practice satisfaction in physicians. *Motivation and Emotion*, *18*, 285–299.

Förster, J., & Strack, F. (1997). Motor actions in retrieval of valenced information: A motor congruence effect. *Perceptual and Motor Skills*, *85*, 1419–1427.

Friedman, R. S., & Förster, J. (2000). The effects of approach and avoidance motor actions on the elements of creative insight. *Journal of Personality and Social Psychology*, *79*, 477–492.

George, J. M., & Zhou, J. (2002). Understanding when bad moods foster creativity and good ones don't: The role of context and clarity of feelings. *Journal of Applied Psychology*, *87*, 687–697.

Gick, M. L., & Holyoak, K. J. (1980). Schema induction and analogical transfer. *Cognitive Psychology*, *12*, 306–355.

Gilhooly, K., & Murphy, P. (2005). Differentiating insight from non-insight problems. *Thinking & Reasoning*, *11*, 279–302.

Hattori, M., Sloman, S. A., & Orita, R. (2013). Effects of subliminal hints on insight problem solving. *Psychonomic Bulletin & Review*, *20*, 790–797.

Isen, A. M., Daubman, K. A., & Nowicki, G. P. (1987). Positive affect facilitates creative problem solving. *Journal of Personality and Social Psychology*, *52*, 1122–1131.

Jaušovec, N. (1989). Affect in analogical transfer. *Creativity Research Journal*, *2*, 255–266.

Jovanovic, T., Meinel, M., Schrödel, S., & Voigt, K. I. (2016). The influence of affects on creativity: What do we know by now? *Journal of Creativity and Business Innovation*, *2*, 46–64.

Kaufmann, G., & Vosburg, S. K. (1997). "Paradoxical" mood effects on creative problem solving. *Cognition and Emotion*, *11*, 151–170.

Kaufmann, G., & Vosburg, S. K. (2002). The effects of mood on early and late idea production. *Creativity Research Journal*, *14*, 317–330.

Kim, S., Hasher, L., & Zacks, R. T. (2007). Aging and a benefit of distractibility. *Psychonomic Bulletin & Review*, *14*, 301–305.

Mednick, S. A. (1962). The associative basis of the creative process. *Psychological Review*, *69*, 220–232.

Metcalfe, J. (1986). Premonitions of insight predict impending error. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *12*, 623–634.

Mitchel, R. L. C., & Phillips, L. H. (2007). The psychological, neurochemical and functional neuroanatomical mediators of the effects of positive and negative mood on executive functions. *Neuropsychologia*, *45*, 617–629.

Moss, J., Kotovsky, K., & Cagan, J. (2007). The influence of open goals on the acquisition of problem-relevant information. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *33*, 876–891.

Nishida, Y., Orita, R., Hattori, M., Custoldi, V., & Macchi, L. (2018). Novel idea generation and inhibitory function in insight problem solving. *Cognitive Studies: Bulletin of the Japanese Cognitive Science Society*, *25*, 100–114. (In Japanese with English abstract.)

Ogawa, T., Monchi, R., Kikuya, M., & Suzuki, N. (2000). Development of the General Affect Scales. *Japanese Journal of Psychology*, *71*, 241–246. (In Japanese with English abstract.)

Orita, R., Hattori, M., & Nishida, Y. (2018). Development of a Japanese Remote Associates Task as insight problems. *Japanese Journal of Psychology*, *89*, 376–386. (In Japanese with English abstract.)

Phillips, L. H., Bull, R., Adams, E., & Fraser, L. (2002). Positive mood and executive function: Evidence from Stroop and fluency tasks. *Emotion*, *2*, 12–22.

Robertson, S. I. (2017). *Problem solving: Perspectives from cognition and neuroscience*. Philadelphia, PA: Psychology Press.

Rowe, G., Hirsh, J. B., Anderson, A. K., & Smith, E. E. (2007). Positive affect increases the breadth of attentional selection. *Proceedings of the National Academy of Sciences of the United States of America*, *104*, 383–388.

Schwarz, N., & Clore, G. L. (1996). Feelings and phenomenal experiences. In E. T. Higgins & A. Kruglanski (Eds.), *Social psychology: A handbook of basic principles* (pp. 433–465). New York, NY: Guilford Press.

Schwarz, N., & Skurnik, I. (2003). Feeling and thinking: Implications for problem solving. In J. Davidson & R. Sternberg (Eds.), *The nature of problem solving* (pp. 263–292). Cambridge, England: Cambridge University Press.

Stangor, C. (2014). *Research methods for the behavioral sciences*. Toronto, Canada: Nelson Education.

Sternberg, R. J., & Davidson, J. E. (1995). *The nature of insight*. Cambridge, MA: MIT Press.

Suzuki, H., & Fukuda, H. (2013). Unconscious nature of insight problem solving: An analysis using subliminal priming by continuous flash suppression. *Cognitive Studies: Bulletin of the Japanese Cognitive Science Society*, *20*, 353–367. (In Japanese with English abstract.)

Terasaki, M., Kishimoto, Y., & Koga, A. (1992). Construction of a multiple mood scale. *Japanese Journal of Psychology*, *62*, 350–356. (In Japanese with English abstract.)

Tidikis, V., Ash, I. K., & Collier, A. F. (2017). The interaction of emotional valence and arousal on attentional breadth and creative task performance. *Creativity Research Journal*, *29*, 313–330.

(Received February 1, 2018; accepted September 20, 2018)