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On The Effectiveness of Incidental Hints in Problem Solving Revisiting Norman Maier and Karl Duncker[1]

Gestalt Psychology and the Unconscious

In a recent paper Hellmuth Metz-Göckel (2011, 201, translation FR) stated: "Of course the assumption of unconscious processes is also not new in gestalt-theoretic literature. But it was seldom addressed and plays no explicit role in theory." And by mentioning Koffka (1928) and Metzger (1975) he certainly has picked out the most prominent scholars in respect to this topic.

In this paper, however, we would like to focus on a less well-known branch of gestalt psychological research which has so far had little impact on recent research: the investigation of the impact of incidental or unconscious hints in problem solving processes.

Norman Maier, a US-American researcher who came to Berlin to work with the members of the *Berlin Gestalt School*, was probably the first to explore incidental (unconscious) hints using his so-called 'two ropes problem' (Maier 1931): two ropes were hanging down from the ceiling and the subjects had to tie them together; however it turned out immediately that the two ropes were too far removed from each other to be both grasped at once. There were a few items such as a chair, a stick, a pair of pliers, a wire, and a clamp in the room which could be used in order to solve the problem. Those participants who had not solved the problem after ten minutes of work on it were given several aids. Aid 1 consisted of an unnoticed, unconscious hint: the experimenter walked across the room to the window to open it; in passing the ropes he accidentally brushed against one of the ropes and put it into slight pendulum motion. The results show "that subjects who experienced the solution as a whole [after hint 1 was given] failed to report that hint 1 aided them in finding the solution." (Maier 1931, 187)

This description clearly shows that incidental hints are presented supraliminally; it is only their character of being a hint for solving the task that remains unconscious.

Karl Duncker in his book *Zur Psychologie des produktiven Denkens* (1935/1974) touched on the same phenomenon when he was discussing his 'radiation prob-

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lem'. The participants had to find a way to free a patient with a malignant inoperable tumor in the stomach. There exists a special kind of ray, which, albeit harmless at a low intensity, at a sufficiently high intensity will destroy the tumor; however, the ray will also destroy the healthy tissue. How can the latter be avoided? The solution consists of finding that several low-dose rays have to be applied from different angles but all concurring at the location of the tumor. By adding their doses at this location they will be able to destroy the malignant tumor while leaving the surrounding tissue unaffected. Duncker claimed that an incidental hint could facilitate the solution process: either talking about a crossing or painting a cross might trigger the solution in the subject if the problem representation and conceptualization of potential solutions already would point in that direction. (Knoblich & Öllinger 2006, 35f)

Despite the fact that the use of incidental (unconscious) cues for solving problems is an interesting technique for investigating unconscious information processing, Maier's and Duncker's experiments have not stimulated much research. To date only a handful of experiments has been conducted based on this paradigm: while the impact of incidental unconscious cues during an impasse has been explored by Knoblich & Wartberg (1998) and Moss, Kotovsky & Cagan (2007 & 2011), in the experiments of Judson, Cofer & Gelfand (1956) and Grant & Spivey (2003, experiment 2) the impact of cues which were presented right from the start of a problem solving process were investigated. While such a small number of experiments may raise some doubts concerning the robustness of this phenomenon, neurological support has been provided for instance by Reverberi & colleagues (2005) demonstrating that a group of patients with lesions in the prefrontal cortex, usually associated with higher cognitive functions such as decision making and reasoning, outperformed a group of healthy subjects on complex arithmetic matchstick tasks.

Experiment

In what follows an experiment will be presented which aims at contributing to the yet still small amount of evidence confirming the influence of an incidental (unconscious) stimulus.

Hypotheses

The aforementioned studies suggest a positive effect of incidental cues on the quality of the problem solving process. The subjects of this experiment worked on a sequence of four similar complex geometrical matchstick tasks. It is predicted that the continued presentation of an unconscious solution cue from the start will have beneficial effects in comparison to a control group without any cue presentation. In particular it will be tested whether unconscious solution cues have a

positive impact on the number of solved tasks (hypothesis 1), the amount of time necessary for solving the tasks (hypothesis 2), on the type of solution (wave form solution type vs. non-wave form solution type (stair & pattern)) (hypothesis 3).

Method

Design and Participants

The reported experiment was designed as a classical posttest only randomized study (between design). 99 participants (all native German speakers, average age 20,31 years) volunteered in this experiment (convenience sample): twenty-six were students from the Department of Educational Science at the University of Salzburg (average age: 26,4 years) and seventy-three were students of an Austrian Secondary School (grades 12 and 13; average age: 18,1 years); 94 percent of the participants were females. Subjects were randomly assigned to one of four different rotation variants of one of two groups: group one: control group (no treatment); group two: treatment group (hidden, unconscious solution cue (logo) presented from the start of working on the first of the four tasks).

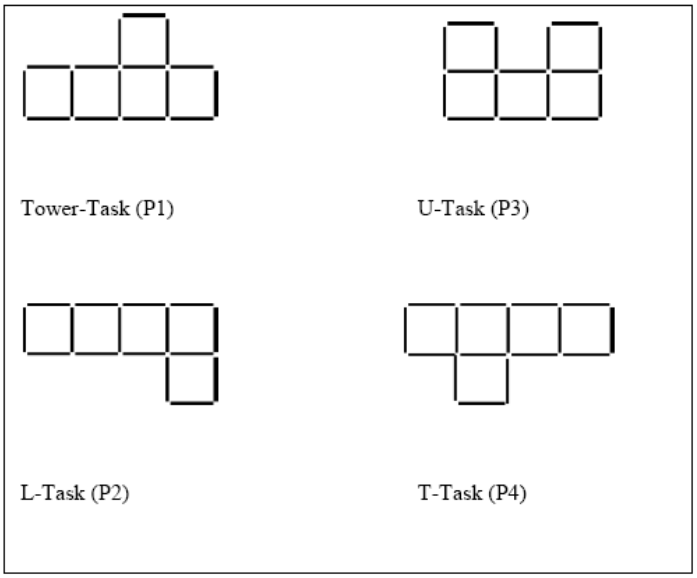

Fig. 1 Start condition of the four match stick problems (P1-P4) and their names.

Material

The participants had to solve a sequence of four geometric match stick problems (see Figure 1) which were taken from Gestalt psychologist György Katona's book *Organizing and Memorizing Studies in the Psychology of Learning and Teaching* (1940) and so far have not been used in this type of research.

The participants had to transform the five-square-figure into a four-square-figure by changing the position of exactly three match sticks. The four squares had to be connected at least at their corners and the match sticks are not allowed to be simply replaced, broken or put on top of each other. Each participant was handed out a detailed instruction sheet which they had to study before starting to solve the tasks. For each one of these four tasks there exist at least two different solutions; one of the solutions of each task is identical in form, it is called "wave solution" (see Figure 2).

Fig. 2 The "wave solution"; this figure was one of the correct solutions of each task.

The unconscious hint was hidden in the logo of a fake research group (Mind, Brain and Education Division) conducting this experiment (see Figure 3).
In order to ensure that the participants did (supraliminally or at least unconsciously) notice the logo (into which the incidental solution hint, i.e. the "wave form", was embedded), the essential part of the logo (the cue) was printed in green color and the participants had to write the start and end time of their solution activities for each task into an empty frame positioned immediately beneath the logo.

Fig. 3 Fake logo plus embedded incidental solution cue (wave form of logo).

According to Dörner's categorization of problem types the used tasks have to be qualified as so-called synthetic problems: their starting condition is known and the end condition (aim) is clearly specified while the operators (specific operations) necessary to transform the start condition into the end (aim) condition are not. (Dörner 1976, 13) However, since the end condition is only very abstractly defined the used tasks tend towards the dialectic problem type which leaves the end condition open. For solving synthetic tasks primarily heuristics of restructuring and discovery have to be applied which leads (frequently) to sudden insights (aha-effects) in the solvers (Arbinger 1997, 70ff).

Finally, at the end of the experiment, the participants had to answer a questionnaire which consisted of items (a) collecting information on social statistics (gender, age), (b) evaluating the quality of the instruction, the motivation during the work on the tasks, the familiarity with the four employed tasks and (c) three items aimed at exploring whether the participants had consciously noticed the relevance of the logo for solving the tasks.

Procedure

There were two groups: one of them was the control group; the participants were given the instructions and had to solve the four problems in the given sequential order. The participants of the second group (intervention group) did in addition receive a hidden cue (unconscious hint). This cue was present from the start of the experiment (first page of the test booklet).

The four geometric match stick tasks were counterbalanced by rotation in order to avoid position effects. They had to be worked on in the sequence presented in the test booklet. For each task the participants had a maximum of ten minutes to find a solution. Before they began to work on each task they had to note the start time in the frame beneath the logo; if they had not solved the problem within that time span they had to turn to the next task and start immediately working on this task after having noted the start time again. If they had solved the problem they also had to continue to the next task on the next page of the booklet and note the start time.

After working on all four tasks the participants had to fill in a questionnaire (for details see above) which was identical for both groups.

Results

Following the recommendations of Cohen (1988, 1994), Gigerenzer (2004) and Lipsey & Hurley (2009), in addition to null hypothesis significance testing effect sizes and information about test power will be provided.

Four participants had noticed the relevance of the embedded incidental hint for solving the problem; therefore they were excluded from further calculations.

Hypothesis 1: Solution Rate

First a new variable, consisting of the sum of all solved tasks, was calculated. The descriptive statistics show (Figure 4) that the subjects of the control group (group 1) solved on average 1,54 tasks while the subjects of the treatment group (group 2) were able to solve 2,34 tasks – a plus of about 50%. Since the values of this variable were not normally distributed a Mann-Whitney rank sum test was selected to compare the control group with the treatment group. The obtained results show that the treatment group differs significantly from the control group

(z=-2,27, p=.023). The medium rank for the control group was 41,88 and for the treatment group 54,26; Cohen's d showed a medium effect: d=.47.

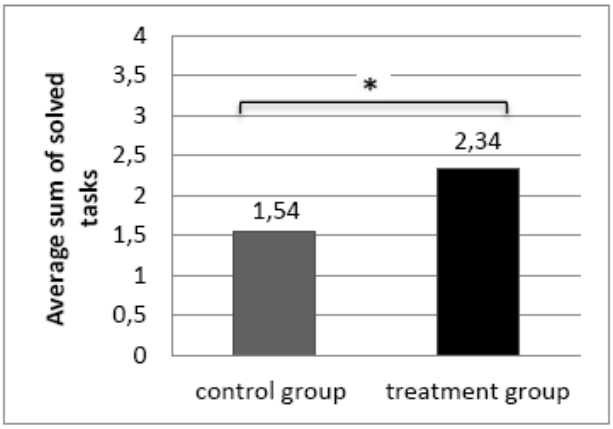

Fig. 4 Average solution rate of both groups (control vs. treatment) *…p<.05

In a second step the task sequence was analyzed to gain a more detailed view. The result shows the following picture (Figure 5): about 60% of the subjects of the treatment group solved each task while in the control group only about 40% did so. So compared to the control group the subjects of the treatment group in sum solve about 50% (!) more tasks – a difference stable over all four tasks while improvement in solution rate over the sequence of all four tasks is not impressive (ranging from 55% for task one to 68% in task four for the treatment group and from 38% to 46% in the control group.

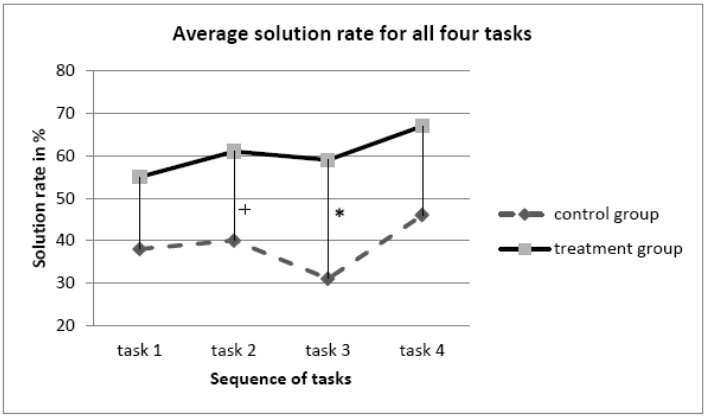

Fig. 5 Solution rate of the two groups according to presentation sequence of the tasks, *… p<.05; +…tendency towards significance (task 2: p=.051).

Despite this impressive difference Chi-square tests showed that tasks two and three reached the level of significance. This is due to the low test power. But the effect sizes (phi) show moderate effects (for tasks 2 & 3) and weak effects (for tasks 1 & 4). (For conventions concerning the interpretation of the magnitude of associations in contingency tables see: Rea & Parker (1992)).

Finally for each of the four tasks (P1, P2, P3, P4) a Chi-square-test was performed and the effect size (phi) was calculated (see: Figure 6).

P1 – Tower-Task: While only 39,6% of the subjects in the control group could solve that type of task, 53,2% in the treatment group could solve it. These differences did not reach significance: Chi-Square=1,77, df=1, p=.184; effect size being small (r=.14).

P2 – L-Task: 35,4% of the subjects in the control group but 55% of the treatment group were able to solve this task; this difference almost reached significance (Chi-Square=3,8, df=1, p=.051), the effect size being moderate (r=.20).

P3 – U-Task: 35,4% of the control group and 53,2% of the treatment group were able to solve this task. This difference did not reach the proposed level of significance: Chi-Square=3,04 df= 1, p=.081; r=.18.

P4 – T-Task: The Chi-Square test showed a significant result: Chi-Square=7.96, df=1, p=.005 and a had a moderate effect size (r=.29).

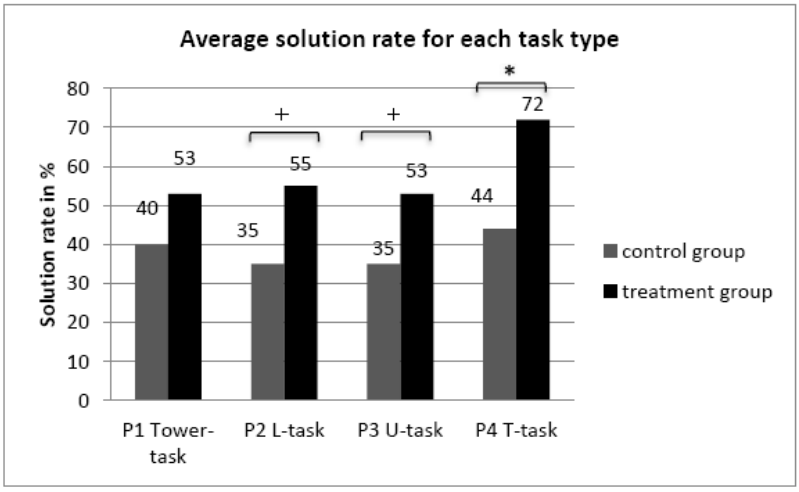

Fig. 6 Percentage of solutions for all four different tasks in both groups. *...p<.05, +…tendency towards significance (P2: p=.051; P3: p=.081).

To summarize, it has been shown that (a) the treatment group (incidental unconscious cue) shows better results for all four tasks than the control group and the differences are unexpectedly high; despite the given low test power still for

one of the tasks (P4) this difference was statistically significant; for tasks P2 and P3 tendencies towards significance were obtained. Comparison between the control and treatment groups for the sum of all solved tasks also reaches the level of significance and in addition a medium effect size. An analysis of the different problem types also shows that for two types (L & T-task) significant results are obtained.

Hypothesis 2: Solution Time

In order to investigate whether the unconscious hint also has an effect on the solution time, a variable was created which contains the average solution times of all four tasks for both groups (Figure 7).

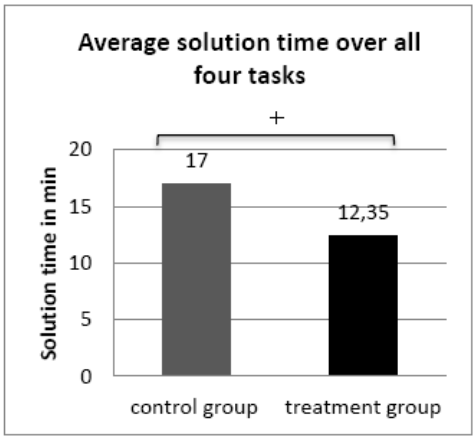

Fig. 7 Average solution time for all solved tasks and both +…tendency for significance (p=.078).

Figure 7 shows the comparison of the average solution time for all four tasks for both groups: the subjects of the control group on average solved all four tasks after 17 minutes; the subjects of the treatment group only needed 12.35 minutes to reach the solution. Since only those subjects could be included in the calculation who had solved *all four tasks* the number of subjects is rather small (control group: n=9; treatment group: n=17) and therefore the test power was very weak (28%). For the test of significance again the Mann-Whitney rank sum test was performed. Control vs. treatment group shows a tendency towards significance: z=-1.77, p=.078. Despite the fact that on average the treatment group is 4,65 minutes faster in solving all four tasks (about one quarter less time is needed by the treatment group than by the control group) the test only yields a so-called tendency. This, as already indicated above, is however due to the extremely low test power of 28%. This interpretation is confirmed by a Cohen's d which shows a medium effect: d=.58.

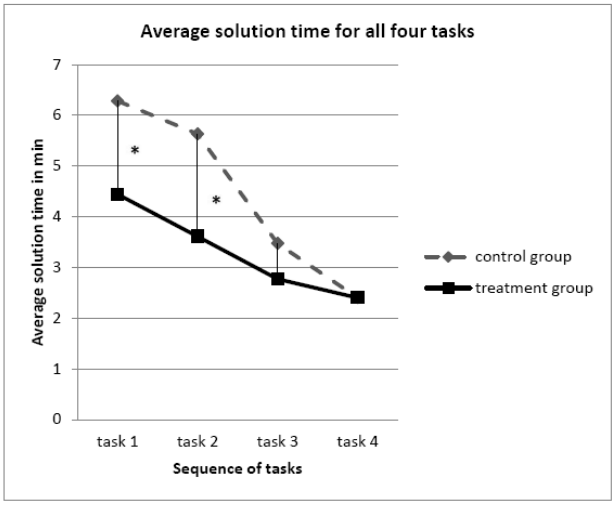

Fig. 8 Average solution time of the two groups according to presentation sequence of the tasks, *…p < .05.

In a second step the sequence of tasks (as presented to the subjects under rotation condition of the different task types) were investigated; the results are presented in Figure 8. It shows that for the first task it took the subjects of the treatment group on average only 4,44 minutes to solve it while the subjects of the control group needed 6,28 minutes to reach a solution; this difference was statistically significant (t(41)=2,29, p=.025) and a medium effect was calculated: d=.67. Concerning the second task the situation is similar: while treatment group one only needed 3,61 minutes to reach the solution the control group needed 5,36 minutes on average. Again this difference reached significance (z=-1,98, p=.047) and the effect size is medium: d=.62 (test power: 51%). For both groups the solution time due to learning processes decreases from task to task, converging towards a bottom line (floor effect). Therefore it is not surprising that the difference in solution time for the third and fourth task does not reach statistical significance. Finally, in order to further investigate the potential influence of the unconscious clue on the time necessary for solving the tasks in more detail, each task type (P1, P2, P3, P4) was examined separately. Descriptive results show that the subjects of the treatment group in comparison to the control group in all four tasks were faster in reaching the solution. Mann-Whitney rank sum tests between the control and treatment groups were not significant, Cohen's d show for the L-task and the Tower-task a medium effect size: d=.60 and d=.70 respectively. That a difference in solution time of about 2 minutes and medium effect sizes do not reach the level of significance, again, is due to the weak test power (57%).

In sum the obtained results confirm hypothesis 2: (a) the comparison of the average solution time of all four tasks shows a tendency towards significance (p=.078)

although the test power was very weak (28%); effect size however shows medium size. An analysis focusing on the sequential order of the four tasks shows that the difference between treatment and control group for the first two tasks of the sequence reach significance and show medium effect sizes (d=.67 and d= .62 respectively).

Hypothesis 3: Solution Types

According to the specific structure of the selected tasks two different solutions are possible for each task. One of these two solutions is identical over the four tasks; it is the primed "wave solution". This offers the possibility of testing whether one of the solutions (the one primed via the unconscious cue (logo)) is found more often by the primed subjects of the treatment group than by the non-primed subjects of the control group.

In order to answer this question cross tabulations (solution type x groups) were planned; it could be demonstrated (see Figure 9) that overall the primed solution was found more frequently in the treatment group (wave solution: 83.6%, other solution: 16.4%, n=110) than in the control group (wave solution: 68.9%, other solution: 31.1%, n=74), Chi-Square=7.96, df=1, p=.019, r=.17. A separate analysis for four problems was conducted on a descriptive level, since for all four tasks more than 20% of the cells had a very low expected frequency so the presuppositions for the calculation of a Chi-Square test were not met.

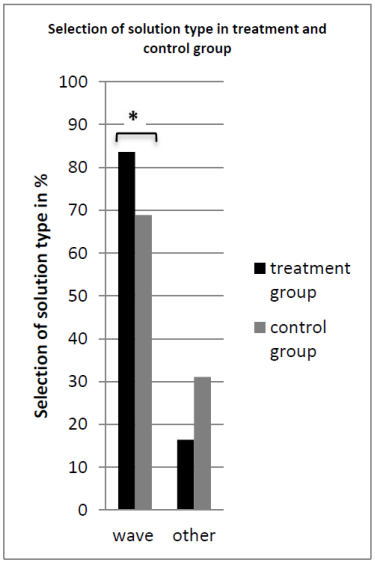

Fig. 9 Overall results - selection of solution type: wave vs. other (none wave) solution in treatment and control group; *… p<.05.

The graphics of Figure 10 show a trend: there was a preference towards the wave-

form solution for the treatment group (although there also seemed to be a natural bias towards the wave solution in the non-primed control group); in three of four tasks the wave-form solution was found more often than the alternative solution type (in all cases relative to the stair solution type). In the L-task 77% of the test subjects in the control group selected the wave solution while in the treatment

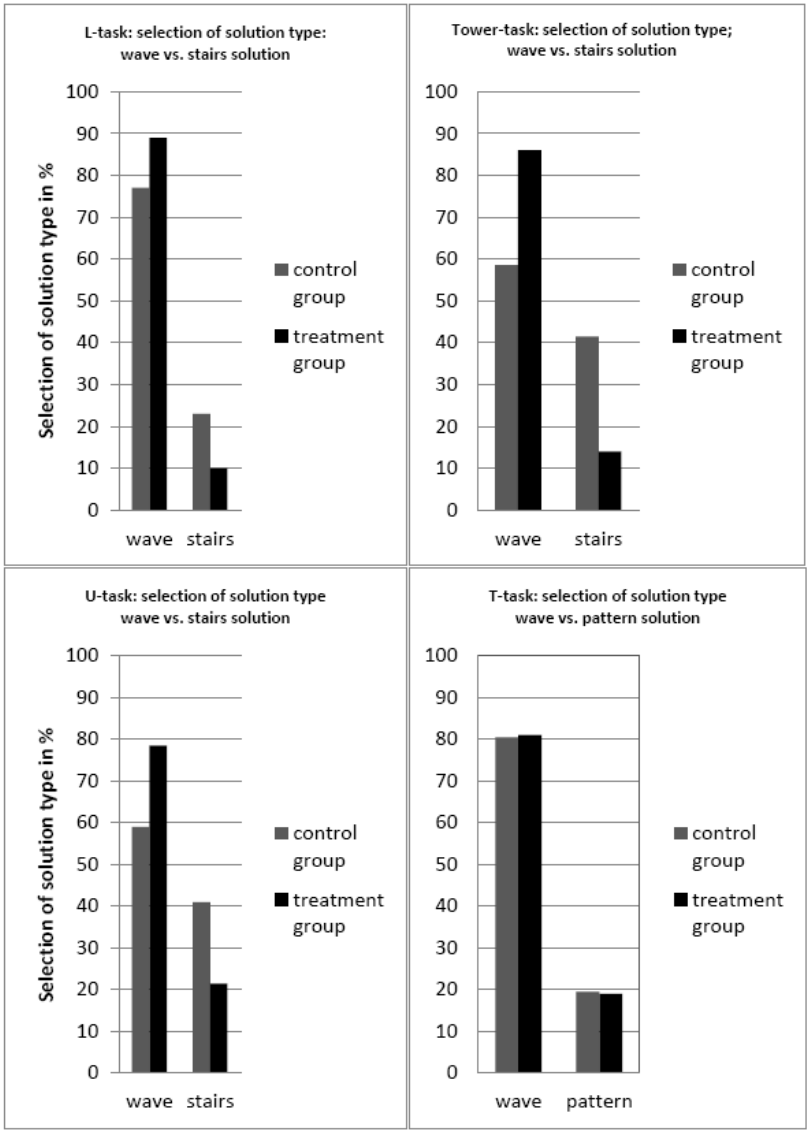

Fig. 10 Selection of solution types: wave vs. non-wave forms (stairs & pattern) of solution for all types of tasks.

group 89% did so; in the U-task 59% of the test subjects in the control group but 78,5% of the treatment subjects chose the primed solution; finally 58,5% of the test subjects without priming chose the wave solution type but 86% of the test subjects who received priming of the wave solution chose this type of solution in the Tower task. Although no test for significance could be estimated these results fit in with the previous results on solution rate and solution time; no such difference was found for the T-task.

Since the obtained descriptive results for three tasks correspond to the results of hypotheses 1 and 2 it seems reasonable to accept hypothesis 3 as well.

Discussion and Final Remarks

The results of the presented experiment on a complex problem solving task confirms that incidental (unconscious) hints have a positive impact on (a) the solution rate and (b) the time necessary for solving the tasks; they also (c) indicate that the selection of the primed solution type ('wave type') is preferred. Therefore once more the effectiveness of incidental hints is demonstrated. These findings are in line with the results published on this topic (Knoblich & Wartberg, 1998; Moss, Kotovsky & Cagan, 2007 & 2011; Judson, Cofer & Gelfand, 1956; Grant & Spivey 2003) and add to the empirical evidence that there are conscious as well as unconscious processes involved in problem solving (Berry & Dienes 1993; Shames 1994; Dienes & Berry 1997; Sun & Mathews 2005).

In addition the results indicate that the gain obtained by incidental (unconscious) solution hints is surprisingly high: 50% more tasks are solved on average by the treatment group than by the control group. The improvement over the sequence of all four (similar) tasks shows only a moderate improvement (treatment group: 55% (task 1) to 67% (task 4), control group: 38% (task 1) to 46% (task 4)). Solution time, on the other hand, decreases sharply for both groups: starting from 6,28 and 4,48 minutes in the first tasks (for control and treatment group respectively) they converge towards a floor value of 2,4 minutes. So it seems that for both groups (control and treatment) over the sequence of all four tasks the gain in solution rate is moderate while the gain in reduction of solution time is strong. One can, of course, speculate whether this indicates that those who are able to solve this type of problem profit in that they become faster at solving the problems while there is only moderate gain in solution rate for those who were not able to solve this type of problem. A more detailed analysis in fact shows that at least those subjects who have solved all four tasks improved over the sequence of all four tasks in regard to solution time; but, however, there are also 27% of subjects who solved task one but then failed to solve either one or more of the following tasks.

The presented experiment opens possibilities for investigating the interaction between the two modes of information processing – unconscious and conscious

(Berry & Broadbent 1988; Sun, Slusarz & Terry 2005; Sun, Mathews & Lane 2007; Helie & Sun 2010): for instance the subjects could be presented with different types of explicit and incidental implicit hints which also could be so arranged as to support each other by providing converging information for one of the two possible solutions for each task, or to provide divergent information, each pointing towards one of the two different possible solutions. (This is possible since, as indicated above, each task has two different (correct) solutions.)

Research on incidental (unconscious) cues holds even more interesting research options. For instance it would be fertile to systematically vary presentation time, duration and frequency of the incidental hint; this would allow for investigating how and to what extent the incidental solution stimuli function in the solution process. Also the incidental cue can be varied from only slightly constraining the problem space up to the presentation of the full solution (since three match sticks have to be altered in order to reach the solution). But also the type of hint can be varied since each of the used tasks has two different solutions. This would open the possibility of testing whether the less preferred solution (under normal solution conditions) can just as effectively be primed as the preferred one, and it might also make possible the execution of Chi-Square tests. Another option is investigating the role of impasses on the problem solving process by presenting incidental hints at different points in time during the solution process.

But the incidental (unconscious) research approach also holds considerable potential applications for the educational domain as well. First steps in that direction have been taken by Chalfoun & Frasson (2008); they implemented an unconscious (masked) solution hint into an online learning task (creating magical squares) and could demonstrate that the students were able to reach better results. Given these results it would be interesting to investigate the impact of improved solving activities, which have been evoked by incidental unconscious hints, on the development of self-efficacy attitudes: according to Bandura (1997) persons with higher self-efficacy convictions select more difficult tasks and work harder at solving the tasks than people with a lower self-efficacy characteristic. Improving such self-efficacy convictions is particularly important for online learning settings where students have to motivate themselves. But also the design of worksheets can be informed by the results of this kind of research. Results from a first explorative study (post measurement only design) point in that direction: for both groups (control and treatment) we have obtained strong and highly significant positive correlations between solution rate and self-efficacy scores: control group ($p<.0001$, $r=.73$); treatment group ($p<.0001$, $r=.66$). These results indicate that success attained with the help of incidental (unconscious) hints contributes to the building up of self-efficacy convictions; of course further investigation is necessary to substantiate this claim.

Finally it is important to draw attention to the shortcomings of the presented experiment: future research will have to ensure that acceptable test power is given. Also a more balanced sample concerning gender is desirable. In general, however, the use of Katona's match stick problems in combination with incidental (unconscious) learning approach holds possibilities for a variety of different designs which allow one to deal with challenging questions (such as the interaction between unconscious and conscious information processes). Experiments which try to improve the quality of obtained results and to investigate more interesting research questions are currently planned as well as performed by the authors.

Summary

Norman Maier (1931) and Karl Duncker (1935) were among those few Gestalt psychologists who presented experimental contributions on the impact of unconscious processes in problem solving. In this article their suggestion to present solution hints supraliminally while at the same time concealing their solution relevance (hint function) and so keeping them unconscious in this respect is taken up again. In a control group design (control group plus one treatment group) the test subjects had to solve four match stick tasks of the same type. The results confirm the effectiveness of the incidental (unconscious) hints concerning solution rate, solution time and solution type (wave form of solution vs. non-wave form of solution). In concluding further potentials of this research approach as well as some educational applications are presented.

Keywords: Problem solving, Gestalt psychology, incidental solution hints, unconscious processing.

Zusammenfassung

Norman Maier (1931) und Karl Duncker (1935) waren zwei jener wenigen Gestaltpsychologen, die experimentelle Beiträge zum Einfluss unbewusster Prozesse beim Problemlösen vorgelegt hatten. Im vorliegenden Artikel wird ihre Anregung, Lösungshinweise zwar supraliminal darzubieten, ihre Lösungsrelevanz aber zu kaschieren und so unbewusst zu halten, nochmals aufgenommen. In einem Kontrollgruppendesign (Kontrollgruppe und Treatmentgruppe) sind von den Versuchspersonen nacheinander vier Streichholzaufgaben desselben Typs zu lösen. Die Resultate belegen die Wirksamkeit der beiläufigen (unbewussten) Lösungshinweise bezüglich Lösungsrate, Lösungszeit und Lösungstyp (Wellenformlösung vs. Nicht-Wellenformlösung). Abschließend wird auf das weitere Potential dieses Untersuchungsansatzes sowie auf erziehungswissenschaftliche Anwendungen eingegangen.

Schlüsselwörter: Problemlösen, Gestaltpsychologie, unbewusste, zufällige Lösungshinweise.

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