Innovation Relies on the Obscure: A Key to Overcoming the Classic Problem of Functional Fixedness

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Abstract

A recent analysis of real-world problems that led to historic inventions and insight problems that are used in psychology experiments suggests that during innovative problem solving, individuals discover at least one infrequently noticed or new (i.e., obscure) feature of the problem that can be used to reach a solution. This observation suggests that research uncovering aspects of the human semantic, perceptual, and motor systems that inhibit the noticing of obscure features would enable researchers to identify effective techniques to overcome those obstacles. As a critical step in this research program, this study showed that the *generic-parts technique* can help people unearth the types of obscure features that can be used to overcome *functional fixedness*, which is a classic inhibitor to problem solving. Subjects trained on this technique solved on average 67% more problems than a control group did. By devising techniques that facilitate the noticing of obscure features in order to overcome impediments to problem solving (e.g., design fixation), researchers can systematically create a tool kit of innovation-enhancing techniques.

Keywords

Since the first study of insight problems (Kohler, 1927), no theory has emerged that can help researchers systematically identify innovation-enhancing techniques for solving toy insight problems (which require only general knowledge about objects) or real-world insight problems (which require specialized knowledge, such as difficult engineering problems). All insight problems require noticing something commonly overlooked that can be used to devise a solution. For an example of a toy insight problem, consider the two-rings problem, in which the participant has to fasten together two weighty steel rings using only a long candle, a match, and a 2-in. cube of steel (McCaffrey, 2011). Melted wax is not strong enough to bond the rings, so the solution relies on noticing that the wick is a string, which can be used to tie the rings together. Once people notice this, they easily devise a way to extricate the wick from the wax (e.g., scrape away the wax on the edge of the cube). For an example of a real-world insight problem, consider the classic invention of mechanical flight, which required moving away from the idea of emulating the movement of a bird's flexible wing to considering the possibility of a fixed wing.

There are two overarching theories of insight-problem solving. In the *representation-change view* (Knoblich, Ohlsson,

Raney, Haider, & Rhenius, 1999; Ohlsson, 1992), subjects initially adopt an incorrect or incomplete representation of the problem and must change it before solving the problem. This view has not led to a systematic approach to problem solving because research based on this framework has not answered what different types of representation change exist and how researchers can help people notice the types that they typically overlook. Second, according to the *distant-association view* (Mednick, 1962), innovative solutions rely on associations that are distant from the concepts of the problem. This view has also not led to a systematic approach to problem solving because research based on this framework has not answered the same types of questions, namely, what different types of associations exist, and how researchers can help people notice the distant members of each type.

In contrast, I have devised a theory that addresses these types of questions and thus allows for a systematic approach to

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the creation of innovation-enhancing techniques. Examining the information required to solve all toy insight problems involving physical objects, the development of 100 recent real-world inventions, and the creation of 1,001 historic innovative inventions (Challoner, 2009) suggests that almost all innovative solutions involve two steps: noticing an infrequently discerned or new (i.e., obscure) feature of the problem and building a solution based on that obscure feature (the *obscure-features hypothesis* of innovation; McCaffrey, 2011). Further, the key obscure features of all these toy problems and real-world inventions fell into one of 32 categories (e.g., parts, material, shape, and size). These features form an extensive category system (i.e., *feature-type taxonomy*; McCaffrey, 2011) that comprises many of the types of features that a physical object might possess.

On the basis of the feature-type taxonomy, researchers can analyze each cognitive obstacle to problem solving in terms of which feature types are being overlooked and why. The classic obstacle is *functional fixedness*, which has been described as the tendency to fixate on the typical use of an object or one of its parts (Duncker, 1945). On the basis of my examination of many inventions and insight problems, however, I characterize functional fixedness as the tendency to overlook four types of features possessed by a problem object (parts, material, shape, and size) because of the functions closely associated with the object and its parts. To overcome functional fixedness, Ohlsson (1992) suggested adding new information about the object or the problem (i.e., elaborating) or reinterpreting old information (i.e., re-encoding). However, how do people specifically go about elaborating and re-encoding?

Knoblich and his colleagues (1999) suggested breaking the objects of the problem into parts (i.e., chunk decomposition), but this technique does not help people fully overcome functional fixedness. For example, in the two-rings problem, subjects need to notice that a wick is a string. Breaking the candle into its parts, wax and wick, is insufficient to move subjects beyond the common use implied by the word "wick": burning to emit light. I propose that subjects should create function-free descriptions for each part. More fully, I propose that subjects can overcome functional fixedness by articulating the parts, material, shape, and size of each object of the problem so that descriptions that imply a use (e.g., a prong of an electrical plug) are replaced by function-free descriptions (e.g., a thin, rectangular piece of metal 0.75 in. long by 0.25 in. wide). Thus, the common use implied by a description (e.g., transport electricity) can hopefully give way more easily to new uses (e.g., use the prong as a screwdriver to solve a particular problem).

Specifically, I propose a method of elaboration called the *generic-parts technique* (GPT), in which two questions are continually asked as a person creates a parts diagram (Fig. 1). For each description a participant creates, he or she should ask, "Can this be decomposed further?" If so, the participant should break that part into its subparts and create another hierarchy level in the diagram. The second question to ask is "Does this description imply a use?" If so, the participant
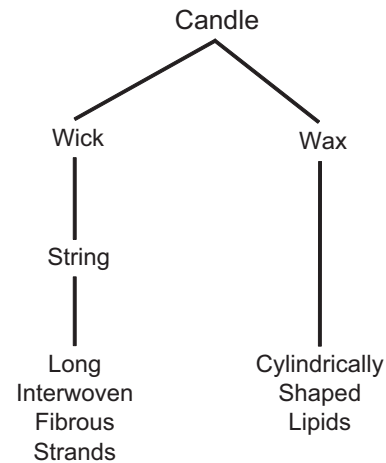

Fig. 1. Example of a generic-parts diagram. Starting with an object (in this case, a candle), participants decompose the object into its component parts and then into generic descriptions of the material and shape of the parts.

should create a more generic description based on material and shape. This procedure results in a tree, in which the description in each leaf (i.e., the bottom level of the tree's hierarchy) does not imply a use and involves the material and shape of the part under consideration. Further, because the parts become smaller as the hierarchy levels progress, this process also calls attention to the size of each of the parts. In essence, the GPT helps subjects think beyond the common functions associated with an object and its parts.

Method

The purpose of this experiment was to test whether learning the GPT helps subjects improve their problem-solving performance, notice more obscure features of the proper types, and identify the key obscure feature required for a solution. Because real-world insight problems require specialized engineering knowledge, I tested the GPT on toy insight problems—which require only general knowledge about objects. Because rigorously performing the GPT will uncover the key obscure feature for all toy insight problems that are known to evoke functional fixedness, this study tested whether subjects could successfully incorporate the GPT into their problem-solving behavior once they learned it. However, this study did not test the implicit effect of just being exposed to the GPT. For this reason, if any subjects had been unable to master the GPT during training, they would not have been allowed to proceed further in the experiment. However, the GPT was easy to learn, so all subjects mastered it.

Subjects

Twenty-eight undergraduate students were recruited from the University of Massachusetts Amherst. A power analysis indicated that this was the number of subjects required in order to achieve a power of .80 ($\alpha = .05$) in detecting an effect size equal to 0.6 (nearly medium, based on Cohen's scale).

Materials

Eight toy insight problems were used: the prisoner-and-rope problem (Isaak & Just, 1995), the candle problem (Duncker, 1945), the circuit problem (Glucksberg & Danks, 1968), the stuck-truck problem (http://www.thinkriddles.com/stuck-semi-riddle-785.html), and four new problems: the two-rings problem, the desk-lamp problem, the wristwatch problem, and the hot-coals problem (McCaffrey, 2011). These problems were chosen because solving them required subjects to overcome functional fixedness.

Procedure

Subjects were randomly assigned to either a control group or a GPT group. All subjects completed one session, which consisted of a training phase (20 min) followed by two testing phases: solving insight problems (60 min) and listing features for 10 common objects (40 min). Each session contained approximately 5 subjects from only one of the groups.

Training phase. Training for the control group consisted of a word association task, in which subjects were presented with 150 stimulus words one at a time. They responded by writing the first word that came to mind. This task has been shown to have no influence on subsequent problem-solving performance (Chrysikou, 2006; Chrysikou & Weisberg, 2005).

During training for the GPT group, the experimenter created and explained the generic-parts diagram for a bell. Subjects in the GPT group then attempted to create two parts diagram on their own for two other objects within 20 min. A subject was allowed one mistake on each parts diagram. Mistakes occurred when either a leaf-node description implied a use or some part had been omitted. All subjects accomplished this task, so none were eliminated from the remainder of the experiment.

First testing phase. Following the design of Chrysikou (2006), the experimenter gave each subject one insight problem at a time on a separate sheet of paper in a randomized order. In each session, subjects worked on the problems in different orders and spent up to 8 min on each problem. When a subject had a proposed solution, he or she showed it to the experimenter. If the experimenter deemed that the solution worked, the subject received the next problem. If the experimenter deemed that the solution did not work, the subject was given a brief explanation as to why and was encouraged to continue working on the problem until the time limit for that problem expired. If a subject wrote down a solution that the experimenter had not seen before, the experimenter said that a panel of three judges would decide later on the efficacy of that solution by a majority vote. The experimenter then encouraged the subject to use the remaining time on that problem to either refine his or her current solution or try to create a second solution.

To encourage subjects in the GPT group to use the GPT, I included a note at the top of each problem sheet stating that the method they learned in the training phase should be helpful in solving the problem. Following Chrysikou (2006), I provided the control group with a neutral statement encouraging them to do their best because the problems were difficult.

After completing this phase of the testing, subjects filled out a questionnaire so their familiarity with the problems could be assessed. If a subject expressed familiarity with any problem, it was eliminated from the data.

Second testing phase. In the second phase of testing, subjects listed features of 10 randomly ordered objects: Five objects were critical to solving the insight problems (e.g., the candle holds the key feature—the wick is a string—for solving the two-rings problem), and five objects were not involved in any of the insight problems. For each object, subjects were instructed to list all its associations, features, and properties in a 4-min time period. Because subjects had questions as to what constituted a feature, for each testing session, the experimenter presented the same example of a coffee cup and described the same four features: "has a handle," "mouth is bigger than base," "handle is shaped like an ear," and "can draw circles with it." The experimenter explicitly said that these were examples of features and that subjects could write down anything that they associated with the object. Before beginning the feature-listing task, the GPT group was encouraged to use the GPT because it could help uncover overlooked features. The control group was encouraged to list all the features they could.

Results

When analyzing the data, I decreased the degrees of freedom accordingly if there was an inequality in the variances between the groups (as measured by Levene's test). There was no significant difference in the number of problems the two groups reported as familiar in the postproblem questionnaire (control group: $M = 0.21$; GPT group: $M = 0.50$), $t(17) = 0.97$, $p = .35$.

The GPT group solved 67.4% more problems than the control group did (GPT group: $M = 82.7\%$; control group: $M = 49.4\%$), which was a significant difference, $t(26) = 4.23$, $p < .001$. The standardized effect size was dramatically large, Cohen's $d = 1.59$ (0.80 is considered large, 0.50 is medium, and 0.25 is small).

Four types of obscure features were targeted in this study (material, shape, size, and parts). To gauge which features of an object were obscure, I conducted a norming study using 15 subjects. In the norming study, subjects were given objects from the eight insight problems used in the main experiment and asked to list the critical obscure feature of each object needed for a solution (e.g., the candle from the two-rings problem). A feature was considered common if 2 or more subjects listed it in the norming study. Common features from the norming study were removed from the lists created in the second testing phase.

In the main experiment, the GPT group listed more target features than the control group did (GPT group: $M = 3.17$;

control group: $M = 1.90$), $t(19) = 2.47$, $p = .02$, and also listed the key obscure feature necessary to solve the problem more often than the control group did (GPT group: $M = 73\%$; control group: $M = 40\%$), $t(26) = 2.20$, $p = .04$. In a follow-up study, a new group of subjects (also divided into control and GPT groups) listed features for the same 10 objects without being exposed to any of the insight problems. Compared with the findings in the main experiment, the results for both the listing of target features (GPT group: $M = 4.28$; control group: $M = 1.87$), $t(24) = 3.80$, $p = .001$, and the listing of the key obscure feature (GPT group: $M = 75\%$; control group: $M = 27\%$), $t(24) = 3.86$, $p = .001$, showed the same pattern. These results suggest that it is not mere exposure to the problems but rather learning the GPT that leads subjects to identify more target features and more often to discern the key obscure feature necessary to solve the problem.

These results strongly suggest that the GPT helped subjects overcome functional fixedness by helping them list more target features, list the key obscure feature more often, and solve more insight problems of the type that normally evoke functional fixedness than control subjects did.

General Discussion

There were four key results of this study. First, subjects who used the GPT solved significantly more insight problems of the type that typically evoke functional fixedness than a control group did. Second, subjects in the GPT group listed more obscure features required for overcoming functional fixedness, including the key obscure feature required for a solution. Third, I redefined functional fixedness as the tendency to overlook four types of obscure features (parts, material, shape, and size). Fourth, the GPT was shown to be a powerful technique in a potential tool kit of innovation-enhancing techniques, in which each technique can be used to overcome a specific cognitive obstacle to problem solving by helping subjects notice the specific obscure feature necessary for a solution. Another such technique, discussed in McCaffrey and Spector (2011), helps subjects successfully overcome design fixation (Jansson & Smith, 1991), which is the tendency people have to fixate on known solutions when trying to create more innovative solutions.

Once there is a technique to overcome all known cognitive obstacles to innovation and a technique to help uncover the obscure members from each of the 32 feature types, then an unsolved problem involving physical objects may be approached in the following manner: On the basis of ever-growing samples of examined problems, researchers can create a probability distribution based on how often each feature type was the key feature for solving a problem. When given a new unsolved problem, researchers can then use the probability distribution to help choose the order in which to try the innovation-enhancing techniques in the tool kit.

The new problem-solving framework tested in this study provides a highly methodical approach to innovation. This approach involves a systematic search process through the feature space using a panoply of techniques that precisely target the obscure members of different sets of feature types. The tool kit of techniques used in this framework contains many specialized tools, which contrasts with the current approach of forming a tool kit of a few general tools (e.g., chunk decomposition and constraint relaxation; Knoblich et al., 1999). I believe that many specialized tools will be more effective for professional problem solvers than a few general tools are, but future research will be needed to test this statement.

Declaration of Conflicting Interests

References

Challoner, J. (2009). *1,001 Inventions that changed the world*. Hauppauge, NY: Barron's Educational Series.

Chrysikou, E. (2006). When shoes become hammers: Goal-derived categorization training enhances problem-solving performance. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *32*, 935–942.

Chrysikou, E., & Weisberg, R. (2005). Following the wrong footsteps: Fixation effects of pictorial examples in a design problem-solving task. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *31*, 1134–1148.

Duncker, K. (1945). On problem-solving. *Psychological Monographs, 58*(5, Whole No. 270), 1–113.

Glucksberg, S., & Danks, J. H. (1968). Effects of discriminative labels and of nonsense labels upon availability of novel function. *Journal of Verbal Learning and Verbal Behavior*, *7*, 72–76.

Isaak, M. I., & Just, M. A. (1995). Constraints on thinking in insight and invention. In R. J. Sternberg & J. E. Davidson (Eds.), *The nature of insight* (pp. 281–325). Cambridge, MA: MIT Press.

Jansson, D. G., & Smith, S. M. (1991). Design fixation. *Design Studies*, *12*, 3–11.

Knoblich, G., Ohlsson, S., Raney, G. E., Haider, H., & Rhenius, D. (1999). Constraint relaxation and chunk decomposition in insight problem solving. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *25*, 1534–1555.

Kohler, W. (1927). *The mentality of apes* (2nd ed.). New York, NY: Harcourt Brace.

McCaffrey, T. (2011). *The obscure features hypothesis for innovation: One key to improving human innovation* (Unpublished doctoral dissertation). University of Massachusetts, Amherst, MA.

McCaffrey, T., & Spector, L. (2011). Innovation is built upon the obscure: Innovation-enhancing software for uncovering the obscure. In A. K. Goel, F. Harrell, B. Magerko, Y. Nagai, & J. Prophet (Eds.), *Proceedings of the 8th ACM Conference on Creativity and Cognition* (pp. 371–372). New York, NY: Association for Computing Machinery. doi:10.1145/2069618.2069701

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

Ohlsson, S. (1992). Information processing explanations of insight and related phenomena. In M. T. Keane & K. J. Gilhooly (Eds.), *Advances in the psychology of thinking* (pp. 1–44). London, England: Harvester Wheatsheaf.