

## A Three-Pronged Approach for Overcoming Design Fixation

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### ABSTRACT

Earthquakes, lightning, and history-changing ideas are classic examples of powerful, unpredictable forces of nature. These sorts of phenomena have been difficult to explain and predict, an often frustrating fact as humans try to understand and control the significant influences in our lives. Historically, such phenomena have been attributed to supernatural sources, such as the Muses or various deities. And yet, as scientific inquiry continues to focus on such problems, we begin to make progress, albeit incremental, in comprehending such unpredictable occurrences.

Earthquakes and lightning serve as analogies for the phenomenon referred to as *insight*. As such, these analogies may help us better understand where ideas come from; in each case, the rare, and potentially powerful phenomenon occurs unexpectedly, yet, as we learn more, it becomes better understood. Lightning is an electrical phenomenon, caused by particles colliding, and building up large electrical fields in the clouds. Earthquakes occur at the edges of tectonic plates, as the Earth releases its heat. Thus, we may begin to understand what causes insight, even though we cannot as yet predict specific occurrences of new insights.

Analogies may not provide fully developed solutions to problems, but they can help us restructure our thinking about certain problems. Problem restructuring is especially appropriate when *fixation* obstructs problem solving. In this paper, we will explain a few of the fundamentals about human insight experiences, particularly in relation to what have been termed *incubation* effects. Putting a fixated problem aside can be helpful, and new ideas encountered during fixation can sometimes trigger new insights, particularly if useful analogies help resolve fixation.

How does one overcome the counterproductive effects of fixation? We suggest a three-pronged approach to this problem: 1. Forgetting fixation, 2. Redefining

problems, and 3. Using clues or hints to provoke new ideas. We will explain each of these ideas, in brief, after providing a background for insight, incubation, and fixation.

## INSIGHT

When someone has *insight* into a problem or a situation, it means that they have a particularly deep understanding of the innermost workings of the problem, and this understanding may include critical ideas that can lead to successful solution of difficult problems. Sometimes, when such an understanding springs to mind in a sudden realization, it is referred to as an *insight* experience, or more colloquially, as an *aha* experience, or a *eureka* moment. These insight experiences are fascinating, because they are, by definition, unexpected, yet they are extremely useful for revealing ideas that are critical for solving seemingly intractable problems. Like a bolt of lightning, or an unexpected shift in the Earth beneath one's feet, historically significant insights have provided unanticipated solutions to scientific problems, ideas for new products, methods for sports or business practices, and society-altering inventions.

## INCUBATION

Incubation effects are cases in which insightful ideas or solutions of problems are realized after the difficult problems temporarily are put aside. When people hear about incubation effects, they usually recognize the phenomenon as one they personally have experienced. Common cases include putting aside a crossword puzzle when you are stuck, and instantly realizing the correct answer upon returning to the puzzle, or putting aside failed attempts to remember a name, only to have the name unexpectedly pop into mind on a later occasion. Thus, the sudden, unanticipated realization that characterizes incubation effects can be an unexpected insight or an unexpected memory. Research has shown that it is possible to reliably observe incubation effects in memory (Choi & Smith; 2005; Smith & Vela, 1991), creative problem solving (Kohn & Smith, 2009; Smith & Blankenship, 1989, 1991; Vul & Pashler, 2007), brainstorming (Kohn & Smith, 2010), and creative design (Smith, Kohn, & Shah, 2010).

Incubation effects are multiply caused; that is, there is more than one cause of the effect. The two causes that have been best supported by scientific evidence are the *forgetting fixation* theory (Smith, 1994, 1995) and the *opportunistic assimilation* theory (Seifert et al., 1995). The opportunistic assimilation theory states that insightful ideas can be triggered by stimuli that are serendipitously encountered at some time after repeated failures have sensitized one to an unsolved problem. Thus, this theory focuses on hints that point the problem solver towards successful solutions. The forgetting fixation theory states that fixation, a cognitive block to successful problem solving, is a precondition for observing incubation effects; in the absence of fixation, problem solutions are realized in straightforward ways. By putting fixation out of mind, at least temporarily, one

can apprehend the problem without the counterproductive influences of inappropriately applied knowledge. This explanation focuses not on pointing towards a solution, but rather on releasing the problem solver from counterproductive work.

## FIXATION

*Fixation* refers to something that blocks successful completion of various types of cognitive operations, including those involved in memory, problem solving, and creative idea generation (e.g., Smith & Blankenship, 1989; Jansson & Smith, 1991; Smith, 1994; Purcell & Gero, 1996; Chrysikou & Weisberg, 2005). Although the term focuses on the harmful aspects of the cognitive processes involved, it is important to point out that these processes are usually quite useful and adaptive. The unconscious cognitive system that rapidly and reflexively reacts to stimuli and situations, enabling automatic responses for highly practiced activities such as reading, driving, or recognizing familiar faces and objects, provides the means for cognitive offloading of highly repetitive responses. This offloading to the *implicit* cognitive system frees up resources for the conscious (*explicit*) cognitive system to carry out more complex activities that cannot be done by rote responses. But, it is precisely because this adaptive implicit cognition is so useful and unconscious that its rare inappropriate use is so difficult to diagnose and repair. Fixation results from the inappropriate and counterproductive implicit use of knowledge.

An example of cognitive fixation in an implicit memory task was first demonstrated by Smith & Tindell (1997). Cognitive psychologists use a number of techniques for testing *implicit memory*, an unconscious reflexive form of memory that is present even in many amnesic patients who have little *explicit* (conscious) memory. After reading a list of words that, for example, contains the word ANALOGY, people, including these amnesic patients, find it very easy to complete the word fragment A \_ \_ L \_ G Y a short time later, because, having recently seen the word, their implicit memory brings the correct solution ANALOGY immediately to mind, without the need for conscious, deliberate attempts to think of a solution. Smith & Tindell (1997), and now others (e.g., Lustig & Hasher, 2001; Logan & Balota, 2003; Leynes, Rass & Landau, 2008; Kinoshita & Towgood, 2001), showed that the word fragment A \_ L \_ \_ G Y is particularly *difficult* to solve, and for the same reason; implicit memory brings instantly to mind the *incorrect* answer, ANALOGY, a word that resembles the correct answer, ALLERGY. Smith & Tindell showed that people cannot avoid this type of fixation even when they are explicitly warned about it.

Similar fixation effects can be seen in creative problem solving. Smith & Blankenship (1989, 1991) found that showing subjects inappropriate hints impedes their ability to solve insight problems and Remote Associates Test problems. Exposure to inappropriate hints also impedes creative idea generation both in individuals (e.g., Smith, Ward & Schumacher, 1993) and in brainstorming groups (Kohn & Smith, 2010).

These studies led to the first demonstrations of *design fixation* (Jansson & Smith, 1991). Engineering design students exposed briefly to flawed designs (see Figure 1) were unable to overcome those flaws in their own designs when asked to design new bicycle carriers, and measuring cups for the blind. Even when they were explicitly instructed not to give designs with drinking straws or mouthpieces in a spill-proof coffee cup, many students who saw an example of such a design produced designs with those explicitly forbidden negative features. This design fixation effect was observed even in professional engineers, who, when shown a highly flawed design for a biomechanical device, reproduced those flaws in their own designs. Figure 1 shows the example designs used to induce design fixation.

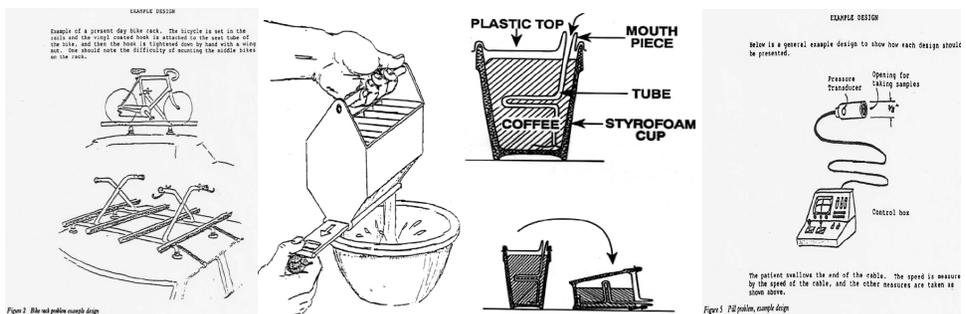


FIGURE 1. Flawed example designs shown to subjects in Jansson & Smith's (1991) experiments.

## FORGETTING FIXATION: STOPPING COUNTERPRODUCTIVE SOLUTION ATTEMPTS

The term *forgetting* can be confusing at times. If I have forgotten the answer for an exam, does it mean that the knowledge has been deleted from my memory? When, halfway to work, I turn around and return to my home to turn off the stove, have I forgotten to turn off the stove or have I remembered it? When I find that I have forgotten your name, have I lost it, or did I ever learn that name at all? If I remember that you have a red automobile, but really, your car is blue, what type of forgetting is that? What does it mean if I go on vacation and forget my problems for a while? Clearly, forgetting is not a unitary thing; there are different types of forgetting. A simple definition of forgetting is a failure to bring learned information to mind, to recognize a familiar known object or action, to execute a planned action, or to properly use a known skill.

Fixation refers to an inappropriate use or application of knowledge or experiences in a particular situation. To forget fixation does not necessitate that it be deleted from one's knowledge or memory. Forgetting fixation means to apprehend one's fixated problem without the inappropriate information or action being used, or without it coming to mind. For example, if you are fixated on using a

certain approach for solving a math problem, and that approach is inappropriate for one particular problem, you need not delete that knowledge from memory to solve the problem; you must simply put the fixated approach out of mind when you apprehend the problem in question. Just as a stand-up comedian must put depressing events out of mind when telling jokes on stage, the designer must be able to put fixating knowledge aside when confronting a seemingly intractable problem.

From the perspective of a cognitive psychologist, there are at least three cognitive mechanisms that would be appropriate for forgetting fixation: 1. Inhibition, 2. Interference, and 3. Context Change. *Inhibition* refers to putting something out of mind temporarily, and is typically accomplished by repeated attempts at suppressing a thought (e.g., Anderson & Green, 2001). To inhibit fixating knowledge requires that first, one must explicitly identify the fixating knowledge; this is not at all easy, since that fixating knowledge is often implicit. *Interference* refers to replacing a fixated response with a different response. Again, this approach is not at all straightforward or easy, because success demands that the fixating knowledge be identified, and an appropriate alternative be available. *Changing context* — does not necessitate explicit identification of the fixating knowledge, nor does it require identification of an appropriate response to replace the fixated one. Apprehending a fixated problem in a changed context encourages or allows you to code or define the problem differently.

There are many historical cases of insights occurring in contexts outside of the regular workplace. For example, Henri Poincare discovered the fuchsian functions while stepping onto a bus to go on vacation. Kerry Mullis thought of the Nobel Prize winning idea for the Polymerase Chain Reaction (PCR) for replicating DNA while he was driving through the countryside. Archimedes discovered the displacement principle, which solved a difficult problem he was working on, when getting into the bath. Kekule thought of the structure for the benzene ring while dozing before the fire. James Crocker, a NASA engineer, thought of an adjustable device for fixing the Hubble space telescope when he adjusted the shower head in his hotel. In each of these cases, and in many others, the unusual contexts in which these historical discoveries were made may have induced the problem solvers to think of their problems differently than the fixated ways that had prevented these insights.

### PROBLEM REDEFINITION

The way that problems are originally defined can cause fixation, especially if the definition one uses implies a particular solution or approach that cannot succeed. Initially fixating definitions may be associated with the typical work context, since that context is likely the one in which previous problems were defined and solved. Thus, one's attempts to redefine design problems might be facilitated by considering fixated problems outside of one's typical working situation.

## CLUES IN THE ENVIRONMENT

There are many examples of how a clue, serendipitously encountered in an unexpected context, triggered an important insight into the solution of a fixated problem. For example, the idea for Velcro came from burrs collected accidentally on a hike through the Alps. As mentioned previously, NASA engineer James Crocker's idea for the Hubble space telescope repair was triggered by a chance encounter with an adjustable shower head. An inventor or designer who is sensitized to a problem by multiple failures might stumble on an important clue, as suggested by the opportunistic assimilation theory (Seifert et al., 1995).

In spite of the theory, the experimental evidence, and the anecdotal evidence of idea triggers in the environment, there are fundamental flaws in terms of applying this method as a solution to design fixation. The first problem is the signal-to-noise problem; that is, there are so many stimuli in any environment! Of the nearly infinite stimuli one stumbles across every day, which one is the relevant one? This problem is by no means trivial. Second, any one stimulus can be encoded in a very large number of ways. Take, for example, a pair of pliers. It could be encoded as a tool, a grasping tool, a tool for increasing leverage, a piece of metal, a conductive material, a plumb weight, a paperweight, a wedge, a property owned by a carpenter, a human artifact, a substitute for a wrench or a vise-grips, a utensil that could be used to grasp food or dead bugs or a hot pan... And that is just a start. Which coding is the one that will help the fixated problem solver? Finally, it is not clear where one should look for a rich source of clues that could trigger insights. A park? A subway station? The internet? What is needed is a place to look for relevant clues that have a good chance of triggering solutions to one's fixated problem.

## ANALOGY

We propose that a rich source of potentially relevant ideas that could help overcome design fixation is the world of analogy. For example, Crocker's idea for the Hubble space telescope repair was an analogy with an adjustable shower head. Velcro was based on an analogy to burdock burrs. A support for a highway overpass might be based on an analogy to a waiter's hand carrying a heavy tray. Nonetheless, simply looking for *any* analogy in the world does not narrow the search for a rich source of potentially useful clues for overcoming design fixation. What analogies are most appropriate for a given design problem?

A method for helping engineers identify linguistically remote (cross-domain) analogies, the WordTree Design-by-Analogy Method (Linsey et al., 2008; Linsey, et al., 2009), is based on the cognitive principles of analogical retrieval. Design problems are represented in multiple linguistic representations at various levels of abstraction to maximize the number of appropriate analogues.

The WordTree Method begins with the key functions of the device being designed, and then linguistically re-represents them in a diagram known as a WordTree. For example, the function of *fold* for a laundry folding device for individuals with disabilities is more generally represented as *change surface* and

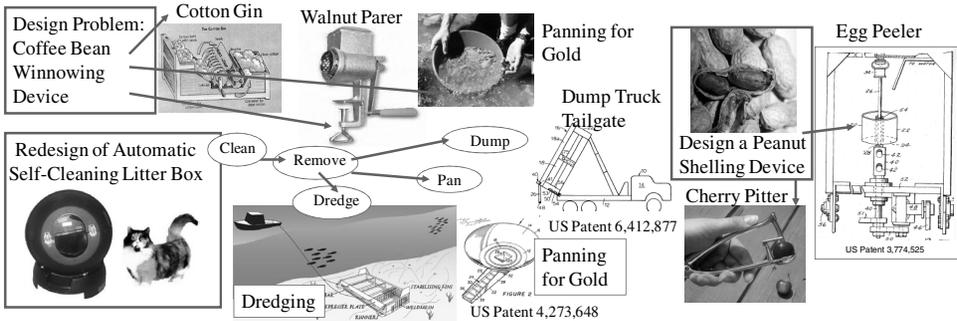


FIGURE 2. Cross-domain analogies identified using the WordTree Design-by-Analogy Method.

more domain specifically as *wrinkle* or *pleat*. Words are added through the designer’s knowledge and WordNet. WordNet is similar to a thesaurus, but structures words hierarchically. After a WordTree has been created, unexpected, innovative analogies can be identified and researched. For example, the WordTree Method highlights *sailing*, and specifically *collapsing* a sail, *dousing*, as an analogous domain. Two effective analogous devices are shown in Figure 3.

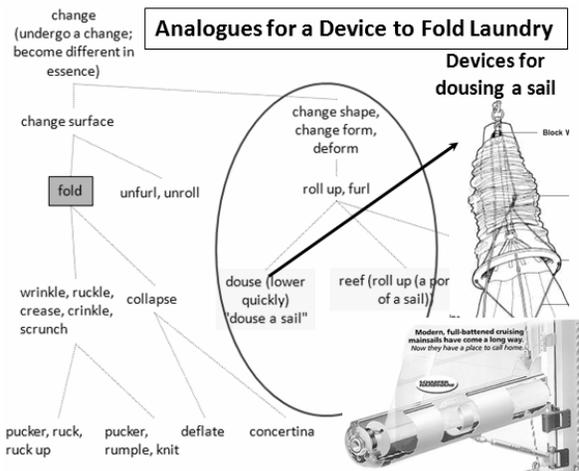


FIGURE 3. Creation of a WordTree allows analogies and analogous domains to be identified and researched. Two analogies based on mechanism for dousing a sail and that are effective for solving the laundry folding problem are shown.

Overcoming design fixation could be done through analogies guided by the WordTree method (Linsey et al., 2009). For example, a designer trying to develop ideas for an inexpensive cocoa grinder requiring no electricity for farmers in developing countries could provide an initial verb (a function) for seeding the

Verb-Tree, such as “grind.” The resulting verb senses might include, “grind, mash, crunch, bray, comminute,” which are different senses or meanings of the seed verb. Once a verb sense is selected, WordTree moves up (hierarchically speaking) to each hypernym (i.e., a more superordinate or general verbal label) for each verb sense that has additional troponyms (i.e., more subordinate, specific verbal labels). One can expand conceptual branches of such semantic hierarchies, following sub-branches more deeply, looking for interesting analogies to spark ideas.

## SUMMARY

The counterproductive effects of design fixation may be overcome using a three-pronged approach: 1. Forgetting fixation, ideally, by shifting contexts, 2. Redefining design problems using abstract functions of designs, and 3. Using analogies to provoke new ideas.

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