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INFORMING DESIGN DEFIXATION USING INTERVENTIONS FOR PSYCHIATRIC DISORDERS

K. Pedret and L.H. Shu*
Dept. of Mechanical and Industrial Engineering
University of Toronto, Toronto, Ontario M5S3G8 Canada
*corresponding author: shu@mie.utoronto.ca

ABSTRACT

Design fixation has been extensively studied in the context of engineering design, leading to several interventions to reduce its negative effects. The concept of mental fixation has roots in diverse psychological contexts from Freudian psychoanalysis to Gestaltism and eating disorders. Although the underlying concepts are similar, the phenomenon has different names, including mental set, rumination, functional fixedness, obsession, etc. Mental fixation in its various forms is often a barrier to problem solving, whether the problem is a psychological disorder or an engineering-design task.

The present paper explores the applicability to design fixation of cognitive therapy, a form of psychotherapy that relies on questioning to identify and modify inaccurate perceptions. Originally developed to treat depression, it is now used to treat a variety of psychiatric disorders. Specific interventions used in cognitive therapy are described in detail towards developing new means of overcoming design fixation. These interventions include cognitive restructuring and exposure response prevention. Also explored are links to other research results from psychology and cognitive science, including focused distraction, and the effects of music and physical exercise. In addition to developing new interventions, existing design-fixation interventions can also be supplemented using insights from these research results.

Keywords: Design creativity, Design fixation, Cognitive therapy, Cognitive restructuring, Depression, Socratic questioning

NOMENCLATURE

Cognitive therapy (CT)	A form of psychotherapy that relies on questioning, and is used to treat a variety of psychiatric problems, e.g., depression.
Cognitive restructuring	Used in cognitive therapy to identify and correct cognitive distortions, or thoughts that cause inaccurate perceptions of reality.
Depression (major depressive disorder)	A serious mood disorder characterized by continuing feelings of hopelessness and sadness with characterized neurobiological markers.
Design fixation	Being overly limited by existing/example ideas and concepts during concept generation.
Defixation	Describes something intended to reduce the negative effects of fixation.
Socratic questioning	A systematic and disciplined method to analyze ideas through dialogue guided by questions.

1. INTRODUCTION

The idea of what mental fixation is and what it does has been explored extensively in diverse contexts, from Freudian psychoanalysis to Gestaltism and eating disorders. Although the underlying concepts are similar, the phenomenon has different discipline-specific names, including mental set, rumination, functional fixedness, obsession, etc. (Freeston et al. 1997, Freud 2016, Maier 1931, Vlugt & Wieringa 2002, Woods & Cook 1999). Mental fixation in its many forms is often a barrier to problem solving, whether the problem is a psychological disorder or an engineering-design task.

The current paper examines mental fixation in the context of conceptual design tasks, generally known as design fixation (Jansson & Smith 1991). Design fixation has been extensively studied in engineering design, resulting in a myriad of interventions to reduce its negative effects (Vasconcelos & Crilly 2016). Although initial research on design fixation was informed by the other forms of mental fixation, more recently, design fixation research has become an entity unto itself. The present paper revisits interventions from psychology, to explore their applicability to design, towards developing new means of overcoming design fixation.

2. DESIGN FIXATION AND DEFIXATION STRATEGIES

Design fixation generally refers to fixations or mental blocks experienced by individuals during the conceptual design process (Jansson & Smith 1991). However, various researchers have defined a broad range of parameters to represent their interpretations of design fixation (Youmans & Arciszewski 2014). Design fixation has been defined as broadly as any form of cognitive interference or low creativity, and as specifically as fixation on a single solution domain or particular design feature (Sio et al. 2015). It has also been described as anchoring a designer's thoughts, and as making a designer's problem solving less flexible (Toh et al. 2014). In the current paper, we adopt Jansson & Smith's (1991) definition of design fixation, "a blind adherence to a set of ideas or concepts limiting the output of conceptual design". This definition is chosen as it is broad enough to include theorized sub-categories of design fixation (as described by Youmans & Arciszewski 2014), while limiting the scope of its influences to the design task.

Researchers describe designers as searching the configuration or knowledge space, i.e., a mental space that contains all domain knowledge and representations of potential concepts (e.g., Jansson & Smith 1991, Howard et al. 2013). Within this space, designers search for potential solutions to their problem at hand. Searches can be both broad (for as many varied solutions as possible), or deep (thoroughly examining one or a small set of solutions). Several studies have operationalized design fixation as the number of produced concepts that lie within only one knowledge domain of the entire solution space (e.g., Linsey et al. 2010). In this vein, design fixation is thought to limit the breadth of the solution space that is searched during the design process, thus hindering innovation and progress.

While not the focus of the current paper, it is worth noting that design fixation can be helpful in certain contexts. By limiting the breadth of the solution space searched, design fixation may help designers more thoroughly examine the solutions or domain on which they are fixated (Sio et al. 2015). This may result in a deeper understanding and consideration of the problem, its context and corresponding solutions, which could then lead to higher quality concepts.

There are two broad categories of defixation interventions, which are used to counter the negative effects of fixation:

1. those that act to overcome or reduce the fixation itself, and
2. those that act to encourage creativity and incite insight.

Other researchers have provided a comprehensive list of defixation strategies (e.g., Linsey et al. 2010) and in-depth reviews of defixation methods (e.g., Vasconcelos & Crilly 2016, Youmans & Arciszewski 2014). Selected and summarized below are widely studied methods to reduce design fixation.

2.1 Incubation

When an impasse is reached while attempting to solve a problem, stepping away from the problem and returning to it later may result in new insights that overcome the impasse. This is known as incubation, wherein a problem-solving deadlock is overcome after focus is shifted away from the problem, leading to some later illumination. Incubation effects are thought to be the product of a change in how retrievable critical information, both useful and un-useful, may be (Smith 1995).

Incubation effects have been tested in relation to design fixation with much success. Off-task incubation (i.e., time spent away from a design problem while focusing on another task altogether) has been shown to reduce design-fixation effects (Smith 1995, Smith & Linsey 2011, Vasconcelos & Crilly 2016, Youmans & Arciszewski 2014).

However, there are different conditions under which incubation may be beneficial or detrimental to the design process. Vasconcelos & Crilly (2016) note that while interruptions during problem-solving enable incubation effects, regular (including improperly timed) interruptions enable fewer concepts to be generated. They further note that taking a break is most effective in yielding the benefits of incubation when done early in the conceptual design phase, but only once an impasse has been reached. Attempting to benefit from incubation when the designer is not yet fixated is less likely to produce valuable insight.

Two theories described by Smith & Linsey (2011) as enabling incubation effects are *forgetting fixation* and *opportunistic assimilation*, where insights are triggered by "serendipitously encountered" stimuli (Seifert et al. 2005). Rather than rely on serendipity, examples can also be actively sought or provided during engineering design, using for example, analogies from biology (Shu et al. 2011).

2.2 Use of examples

The use of examples in design is something of a double-edged sword: on one side, examples help spark inspiration, but on the other side, improper adherence to examples can lead to fixation (Toh et al. 2014). Even the most creative of design solutions are often extensions of existing examples, yet an overreliance on such examples leads to fixation effects (Vasconcelos & Crilly 2016). Thus, the use of examples has been shown to result in both fixation and inspiration under different conditions (Linsey et al., 2010). Vasconcelos & Crilly (2016) note that helpful versus harmful effects of example use depend on what the examples are, their quantity, and the manner and timing of their presentation.

The number of examples presented affects the breadth of the solution space explored. Too few examples may limit the quantity of ideas produced or their similarity to one another, and too many may hinder the quality of ideas (Sio et al. 2015). The number of concepts produced is nonetheless inextricably linked to the diversity of examples produced, which has a clear effect on the resulting fixation or inspiration.

The similarity of exemplars to the design problem is a major factor in fixation. If examples used are too similar to one another, the resulting ideas generated may be numerous but highly similar to the exemplars and each other. Further, should the examples presented all lie within the same domain or category, the resulting solutions produced are likely to also be within that domain or category. Because design fixation is defined as an adherence to a set of concepts, this result may be qualified as design fixation. However, the opposite is also true: using varied examples from different categories produces a greater variety of solutions (Fu et al. 2013).

The modality in which the examples are provided also affects design fixation. Visual analogies and examples seem to improve design problem-solving by increasing the number and

quality of designs produced, whereas examples presented by text or dialogue seem to improve the originality of resulting designs (Casakin & Goldschmidt 1999, Goldschmidt & Smolkov 2006).

The timing of example presentation also affects how helpful or harmful the examples are to the design process. Presenting examples early in the design process is more valuable than late presentation (Vasconcelos & Crilly 2016), but it is critical that the designer has already begun ideation and reached an impasse before the examples are provided (Sio et al. 2015). The susceptibility of designers to examples also depends on how related the examples are to the design problem. When near (i.e., similar) examples are presented, they are most helpful earlier in the problem-solving phase, whereas further (i.e., dissimilar) examples are most helpful later on (Tseng et al. 2008).

Examples should therefore be used with caution. Although experienced designers have many examples stored in memory for potential access (Linsey et al. 2010), controlling access to new examples may be beneficial. A few diverse, multimodal exemplars presented when designers have reached an impasse may help in overcoming design fixation. In contrast, too few or too many similar in-domain exemplars presented early in the design process may hinder a designer's ability to produce multiple novel ideas.

2.3 Prototyping

In addition to using examples to overcome fixation, another source of external cues comes from prototyping and creating physical models. Designer interaction with such models could provide immediate feedback on the feasibility of their concepts at a relatively early stage, thus reducing unproductive fixation.

Further, Vasconcelos & Crilly (2016) suggest that building physical models that are represented externally from the designer's mind reduces mental workload. That is, moving solutions from designer's mental working memory frees up workload and attentional resources. This enables designers to delve deeper into the proposed design and/or consider other possibilities. This in turn, may help overcome design fixation on features of the prototyped model or on the wider domain.

Related to prototyping, product dissection enables a designer to interact directly with a physical representation of the object. Toh et al. (2014) suggest that the act of dissecting a product helps to encourage creativity and design exploration.

Although prototyping may be useful for gaining feedback and freeing mental-workload capacity, Viswanathan & Linsey (2013) warn that it may also have an undesirable effect. Specifically, designers may become attached to a particular concept or solution out of familiarity or work already dedicated to its development, known as the sunk-cost effect. Creating physical models thus comes with a caution that a possible attachment to the modeled concept may reduce the consideration of alternative concepts.

Vasconcelos & Crilly (2016) note that physical prototyping may also foster a mindset of depth over breadth. That is, the effort involved in building prototypes may lead to higher-quality concepts. However, this same effort may reduce resources available to produce other novel ideas, thereby increasing fixation effects. It is therefore important to strike the desired balance between depth and breadth. Thus, for prototyping to help overcome fixation, it is best done early on in the design process, where it can act as early feedback on ideas generated.

2.4 Knowledge of fixation

Next considered is the effect that the knowledge of fixation may have on a designer. If a designer is able to recognize when they are fixated and understand the effects of design fixation, would they more readily be able to overcome it?

Howard et al. (2013) aimed to answer this question by giving some engineering students a lecture on design fixation before completing a group design task. They found that the informed groups produced less-flawed concepts, suggesting that they experienced fewer design-fixation effects than groups who did not receive the lecture on design fixation. Thus, information on design fixation and its negative effects may enable designers to more readily avoid it.

In contrast, Linsey et al. (2010) found that even design researchers, who are highly educated on the topic of design fixation, are still vulnerable to its effects. In their study, design researchers generated fewer novel concepts than a control group not shown fixation-inducing stimuli, e.g., negative design examples.

A possible way to reconcile the above results is that Howard et al.'s participants were explicitly educated on design fixation right before completing the design task. In contrast, Linsey et al.'s participants, while familiar with the concept of design fixation, were not explicitly instructed to watch for its effects. Angello et al. (2015) observed that being explicitly told to avoid fixation-inducing primes reduced fixation effects. Perhaps the direct and explicit reminder to avoid fixation and fixation-inducing stimuli led to the effects that Howard et al. (2013) attributed to knowledge. Additionally, the explicit reminder about design fixation may make participants more consciously aware of its presence. Although designers often may not be aware when they are fixated (Linsey et al. 2010), an explicit pre-task reminder may increase consciousness of design fixation's influence.

2.5 Reframing the problem

Smith & Linsey (2011) also suggest redefining the problem to overcome fixation. The way that the design problem or potential solutions are framed may be the basis for design fixation, anchored on certain concepts or ideas (Smith 1995, Youmans & Arciszewski 2014), and failure to revise or update one's views is fixation (Woods & Cook 1999). If the way the problem is presented is the cause of fixation, then reframing the problem will act to resolve the design fixation (Ostafichuk et al. 2011, Woods & Cook 1999). By problem reframing, i.e., thinking of the problem in a different context from how it was originally presented, one may hope to find a new approach to solve it (Ostafichuk et al. 2011).

Problem reframing can be traced to Gestaltian psychology, which was the basis for the discovery of functional fixedness. Gestaltian psychologists characterized insight (i.e., the opposite of fixation) as the result of restructuring one's mental representation of the problem at hand (Smith 1995).

Although it is a fairly simple idea in theory, there are challenges in using reframing as a method of reducing design fixation. In addition to the question of when to reframe problems if designers are unaware of when they experience fixation, another challenge is *how* to reframe problems.

Motivational theories from social psychology may provide strategies for problem reframing. For example, the simplest model of motivation describes people as approaching pleasure and avoiding pain. Thus, to motivate a person, one can further develop concepts that correspond to either the pleasure of the reward, or the pain of the penalty. More nuanced, Higgins (2000) suggests that people approach and avoid different things depending on their regulatory focus on either promotion- or prevention-focused goals. Therefore, concepts can be developed that appeal to promotion-focused individuals, i.e., by approaching gain and achievement. In contrast, other concepts can appeal to prevention-focused individuals by avoiding the loss of safety and security.

More generally, in designing to modify user behavior, designers can either aim to decrease a harmful behavior, or increase a beneficial behavior. For example, consumers could be penalized for using disposable water bottles, or they could be rewarded for using reusable water bottles. Beyond financial rewards and penalties, some reusable water bottles have been presented as a status symbol, such that consumers are socially motivated to be seen using them. Thus, different sources of motivation can also be used to reframe problems (Shu et al. 2017).

3. PSYCHOLOGICAL CONCEPTS AND STRATEGIES RELEVANT TO DESIGN FIXATION

In addition to the significant body of work on design fixation and interventions as described above, other relevant concepts and strategies exist in fields such as mental health and cognitive science. Although psychological disorders and design fixation may differ in time scale and emotional investment, clinical techniques can potentially be modified to be relevant to, and provide insight for overcoming design fixation.

3.1 Cognitive therapy (CT)

Cognitive therapy (CT) is a psychotherapy method originally developed to treat depression (Beck 1970), and has since been used in a wide variety of psychiatric and healthcare disciplines (Beck & Emery 1985, Beck & Dozois 2011). Based on an information-processing theory of the mind, CT proposes that without accurate information, we cannot overcome cognitive difficulties (Beck & Dozois, 2011). Within this view of the mind, behaviors, thoughts, and feelings are all interconnected. Therefore, problems that arise can often be solved by examining and correcting maladaptive thoughts. In CT, patients work with a trained therapist to assess and improve the accuracy and usefulness of their beliefs through analysis.

CT is based on the premise that through carefully guided probes, patients must first access their erroneous thoughts. It then focuses on helping patients to shift their maladaptive beliefs to be more useful and evidence-based (Beck & Dozois 2011). This change can be accomplished through methods including cognitive restructuring (see Section 3.1.1), and by modifying core beliefs and behaviors.

Within the broader, more recent cognitive behavioral therapy (CBT), CT is a specific approach that encompasses several therapeutic techniques, often used in combination with one another or other therapies. Below, we describe three widely applied CT techniques and their potential to act as interventions for design fixation.

3.1.1 Cognitive restructuring

Cognitive restructuring, a key CT process, aims to identify and correct *cognitive distortions*, or thoughts that cause inaccurate perceptions of reality (Leahy & Dowd, 2002), e.g.,

- Arbitrary inference: Making conclusions with insufficient evidence;
- Selective abstraction: Using only one aspect of the problem or scenario from which to draw conclusions;
- Over-generalization: Drawing undue conclusions from a single event or idea; and
- Magnification (of negatives) and minimization (of positives).

Among other applications, cognitive restructuring is used to treat thoughts that have become over-important, and a need for perfectionistic control and certainty (Freeston et al. 1997). Cognitive restructuring involves 5 steps:

1. Identify the target thoughts or erroneous thinking;
2. Monitor and track the target thoughts;
3. Evaluate the target thoughts;
4. Elicit rational alternatives; and
5. Reappraise the target thoughts using the new insights (Beck & Emery 1985, Freeston et al. 1997, Marks et al. 1998).

Introducing Patient X

As a running example to demonstrate use of these methods, imagine a patient X who is depressed. X is working with a therapist and using cognitive restructuring to overcome his depression. To begin, X's therapist may ask him to explain the source of his depression, e.g., loneliness, and perhaps identify the context(s) that worsen his depressions, e.g., being rejected by romantic partners. To elicit the target thoughts, X could be asked to complete sentences such as "I think I was last rejected because…" X could complete this sentence with a maladaptive, target thought, e.g., "I am unworthy."

The third step, the evaluation of target thoughts is what may be most the applicable from cognitive restructuring to design fixation. In this step, X would work with the therapist to analyze the target (problematic) thought using one or more techniques. For example, X could be asked to list the ways in which he *is* a worthy person. Once this has been completed, X will work to develop rational alternative thoughts based on the previous analysis and replace the target thoughts with more adaptive ones. For example, X could instead think, "My last relationship didn't work out because we did not enjoy the same activities."

Applied to design fixation

For design fixation, target (problematic) thoughts could correspond to unnecessary, designer-imposed requirements that prevent satisfactory solutions. For example, imagine that designer Y has been asked to replace an existing counter top with a particular material, but this material is too heavy for the existing base that she should not replace. Y could struggle between the non-ideal options of replacing the base regardless, or using a thinner counter top that meets the weight constraint but neither looks quite right and nor achieves the previous counter height. Alternatively, Y could recognize that she was unnecessarily constraining the countertop to be the same solid material throughout. Instead, the countertop could have a core made of a different, stiff yet lightweight material.

Methods for evaluating target thoughts

Several specific methods support Step 3, the evaluation of target thoughts (Beck & Emery 1985, Marks et al. 1998). In general, nearly all CT techniques aim to address three basic questions with respect to target thoughts (Beck & Emery 1985):

Q1. What is the evidence?
Q2. How else can the situation be viewed?
Q3. So what if it happens?

To begin, target or problematic thoughts are identified. One method, thought recording, asks a patient to record target thoughts towards identifying the anxiety and the root cause of the anxiety/feelings of distress. These thoughts are then evaluated by methods roughly corresponding to the three questions as follows.

Q1. What is the evidence?

- Analysis of faulty logic: By evaluating the available evidence, this method often acts against the target thought by showing how the patient has jumped to inaccurate conclusions.
- Probabilistic reasoning: This involves reasoning about the probability of one or a sequence of events actually occurring.
- Weighing options: This can be done using a pro/con list or a cost/benefit analysis when evaluating the target thought.
- Socratic questioning: See section 3.1.2 below.

Q2. How else can the situation be viewed?

- Listing rational alternatives and generating alternative interpretations: Here, the therapist guides the patient to consider perspectives other than the direst one, which the patient often considers as the only/most important one.
- Decentering: Wherein the patient is challenged to view the target thought from a point of view that is not their own, i.e., where they are not the focal point.
- Reattribution: The patient is helped to realize that they are not the cause, nor are they responsible, for all negative outcomes, but rather, such things are often beyond their control.

Q3. So what if it happens?

- Decatastrophizing: Also called the so-what method, patients explore what would happen in the worst-case scenario, and realize that the most catastrophic outcome is unlikely.

Beyond evaluating and reappraising target thoughts, the below methods enable coping with their resultant anxiety or distress:

- Modifying/substituting imagery: Here, patients report visual imagery of negative consequences. This often leads to their acting as though these consequences have happened, so therapists may induce more favorable imagery to replace or provide distance from negative imagery.
- Turn-off technique: Here, visual imagery of anxiety-inducing situations is interrupted with overwhelming stimuli, e.g., loud noise or engaging in another cognitively demanding task.

3.1.2. Socratic questioning

Though used as an archetypal sub-technique in cognitive reframing (see above Section 3.1.1), the Socratic method of questioning may unto itself be a valuable technique for overcoming design fixation. Socratic questioning is a systematic and disciplined method to analyze ideas through dialogue (Paul & Elder 2007). Involving two people (often referred to as teacher and student), the teacher asks focused questions to the student while feigning naiveté on the subject matter so that the questions are answered comprehensively.

When patients have worked with a therapist using Socratic questioning, they may later find themselves using the technique *in vivo* (independently) and being able to mobilize the technique as required (Beck & Emery, 1985).

This method of idea examination and dialogue has proven valuable to CT, education, and coaching (Neenan 2009, Paul & Elder 2007). Due to its promise in other disciplines, Socratic questioning has potential to reduce fixation.

Applied to design fixation

The Socratic method can be applied to examine a design problem from other perspectives. Corresponding questions may probe at the purpose of the idea or solution, by asking about the goals, agenda, and audience of the problem and concepts. Questions may ask about supporting evidence, alternative solutions, and potential outcomes to bring focus to the components of reasoning that led to the concept or solution examined (Beck & Emery 1985, Paul & Elder 2007). The Socratic method may even be one way to allow for designers to reframe the problem (see section 2.5). Using such a technique may lead a designer to clarify the crux of a problem, thus revealing new solutions.

Downward arrow technique

Problem reframing by questioning the problem at hand is commonly used in cognitive therapy (Burns 1980). One such technique is known, amongst other names, as the downward arrow technique. Using this technique, a therapist questions a patients' automatic thoughts in a systematic manner. Eventually, after enough iterations of asking, e.g., "and what does that mean to you," the true root cause of the thought is discovered, and often, re-evaluated. Used to uncover (typically negative) self-focused beliefs, the downward arrow technique in clinical practices often leads to the patient revealing a catastrophized belief that underlie an initially surface thought.

For example, Patient X may be asked why he did not attend a recent social event. He could respond and the therapist could repeatedly ask, "and what does that mean to you?" as follows:

Why didn't you go to this social event?
X: Because it was a potluck dinner.
And what does that mean to you?
X: That I would have to bring something.
And what does that mean to you?
X: That people would judge me by what I brought.
And what does that mean to you?
X: They would find what I brought to be not good enough.
And what does that mean to you?
X: That they would find that I'm not good enough.
And what does that mean to you?
X: That I'm not good enough.

Applied to design fixation

Analogous to the downward arrow technique in CT, problem reframing by questioning the problem at hand is commonly used in business analysis. Possibly already familiar to designers, five-whys is a business-analysis method of delving into a problem by asking "why" a minimum of five times (Spradlin 2012). It begins by having the examiner articulate the problem at hand, either by writing or dialogue. Next, the examiner is asked why the problem exists, the subsequent answer is articulated, and the same question is asked of the new answer. This is repeated until the root cause is discovered, often requiring at least five iterations (Serrat 2017).

As with the downward arrow technique, five-whys is a structured way of iterative questioning. While intended to help find the root cause of a problem, it also allows the inquirer to ensure that they are not fixated on trying to solve the wrong problem or making incorrect assumptions about the situation.

For example, imagine that professor Z is struggling to find a different room for a specific seminar in a seminar series. Applying the five-whys technique to this problem may reveal the following:

1. Why can't the usual seminar room be used?
   Z: Because it is ill-suited for this particular seminar.
2. Why is it ill-suited?
   Z: Because the tables are all round and cannot be easily moved due to power cables attached to them.
3. Why can't round/attached tables be used?
   Z: Because the seminar involves a panel session.
4. Why can't round, attached tables be used for a panel session?
   Z: Because panelists should face the audience, and not each other at a round table that cannot be moved or reconfigured.
5. Why do the panelists have to be seated at a table?
   Z: Actually, they may not need a table. I've just always seen panelists seated at a long table. I guess we could just put chairs where the panelists should sit in the usual room, and use other chairs to hold whatever they need near them.

By using the sequence of the five whys, the problem is solved by clarifying the initial (unspoken) assumption to remove this assumption. Because of its rigor and systematicity, the Socratic method and its related questioning techniques may be replicated in a software tool for designers. However, note that in the above example, the final question was not, "Why do the panelists have to face the audience?" Thus, some ability to distinguish more useful questions beyond simply repeating the previous response in the form of a question is required.

Other types of questions used in CT are shown in Appendix A, which lists both the original form of the question by James et al. (2010), and how they could be translated into possible questions relevant to design fixation.

3.1.3 Exposure response prevention (ERP)

Though often spoken of colloquially, facing your fears has research-backed evidence for its effectiveness as a valid behavioral therapy technique. Its more formal protocol, exposure response prevention (ERP), has been successfully used to treat a variety of disorders, such as anorexia nervosa (Steinglass et al. 2011), anxiety disorders (Beck & Emery 1985) and obsessive-compulsive disorder (OCD) (Korrelboom et al. 2008). ERP is often an *in vivo* treatment, wherein patients are exposed directly to the thing that makes them anxious or scared.

Continuing with the example of patient X, should his therapist decide to use ERP to reduce his fear of rejection, X could begin by putting himself in unimportant situations where he may be rejected. For example, X could try to register for an oversubscribed professional course in which he has little interest. The likely "rejection" from this course could demonstrate to X that no catastrophes follow such exposure, and that rejection can be both non-personal and entirely manageable. Following this, X could be asked to expose himself to increasingly more meaningful rejections, e.g., minor platonic social rejections and then minor romantic rejections. Thus, X learns through repeated experience to quell obsessional fear and avoidance of rejection through habituation.

Beck's (1970) proposal of cognitive therapy includes the idea of a fear hierarchy. The first level comprises of obvious fears, e.g., of hurting oneself, dying or humiliation. The second level corresponds to symptoms of anxiety. For example, older adults may recover from the physical injuries of a fall, but may socially isolate themselves due to fear of falling again (Chou et al. 2005). This social isolation may have more negative health effects than the actual fall. Beck & Emery (1985) note that although a patient may not be able to overcome the first level of fear, they may be able to manage the second level. For example, in addition to avoiding social isolation, therapy to overcome this level of fear may include encouraging socialization.

Applied to design fixation

Relevant to design fixation, designers may limit themselves to possibly suboptimal solutions due to different sources of fear and anxiety. Thus, designers could clarify whether the source of their fear is actually catastrophic, e.g., a bridge collapsing if they used a material with which they are less familiar. Alternative sources of fear could be loss of professional esteem if an unnecessary risk turns out poorly, or the extra work required to learn more about a new material or domain of solution.

Therefore, ERP could be analogously applied to address designers' possibly irrational avoidance of certain domains of solutions. That is, designers could be asked to gradually consider and then implement solutions from an unfamiliar domain. Their incremental successes could encourage the increased inclusion of the less-familiar domain in future solutions.

3.2 Distraction

Distraction and attentional shifts have been used in education, sports coaching, and the treatment of obsessive and phobic disorders with some success (Bögels et al. 1997, Wells 2002). Najmi et al. (2009) found that focused distraction is effective in managing intrusive thoughts in patients with OCD.

True to its name, focused distraction is a fairly simple technique wherein the patient controls their attentional resources to focus on stimuli unrelated to that of the intrusive thought. Returning to patient X, when plagued by thoughts of possible rejection, X could use his executive-control functions to actively redirect his attention to something unrelated, such as visualizing his route to work or reading an engaging book.

One formalized protocol for strategic attentional control is the attention training technique (ATT), which has proven successful in a range of psychiatric disorders (Najmi et al. 2009, Wells 2002). ATT is designed to interrupt repetitive thoughts found in an array of psychiatric disorders, such as social phobias and depression. A single ATT session may last up to 15 minutes, and relies on the presence of nine distinct auditory stimuli. First, three of the auditory stimuli are to be identified in the immediate vicinity. Then, three more auditory stimuli are to be identified in the near distance, then again for far distance. The patient is instructed to focus on and identify all three sounds at each distance, forcing an attentional shift by focusing on something other than their problem. Should nine distinct sounds be unavailable, nine competing sounds of varying intensities can be used in the immediate vicinity (Wells 2002).

Wells (2002) notes that ATT should not be used when patients are in a state of rumination, i.e., patients with phobias or those fearing certain events may use ATT inappropriately. Upon realizing that the feared events have not occurred, or they have become less afraid, such patients may wrongly attribute the alleviation of symptoms to the ATT protocol. Rather, the feared event or their phobia was unlikely to be realized in the first place. While a valid concern for anxiety and ruminative disorders, this should not be a problem in design, where lack of inspiration is unlikely feared the same way.

Applied to design fixation

ATT may be applied to design fixation by targeting the fixation in the same way as self-focused attention. Using a modified version of ATT where all nine sounds are within the same vicinity, this may be an accessible and efficient method of focused distraction for design fixation. Once the designer recognizes that they are in a rut, they can play a track with the nine varying sounds of different intensities and attempt to identify each of them. This may pull their attention away from their design task long enough to overcome their fixation.

3.3 Physical exercise and music

Physical exercise (Carek et al. 2011) and music (Van Assche et al. 2015) are also helpful in overcoming depression.

To counter depression, exercise (Knaepen et al. 2010), music (Pecci et al. 2016), and exercise with music (Yeh et al. 2015) have led to physiological changes by increasing available levels of brain-derived neurotrophic factor (BDNF). As a protein essential for brain neuron (nerve cell) growth, function and survival, BDNF is highly susceptible to regulation through aerobic exercise and music. This in turn increases what is more generally known as neuroplasticity, which helps counter the neuronal effects of depression (Knaepen et al. 2010). Low concentrations of BDNF have been linked to the physiological presentation of depression in the brain, particularly in the prefrontal cortex where executive functions are regulated and the hippocampus – a region known for its role in emotional processing and susceptibility to stress (Zhou et al. 2017). The hippocampus is particularly affected in depression, whereby patients with depression show fewer hippocampal neurons (Sheline et al. 2003). Therefore, if BDNF, which incites neuron growth and protects existing neurons, can be stimulated, it may be able to help protect against and regenerate neuronal losses correlated with depression.

Aerobic exercise has been shown to increase available levels of BDNF in the brain for up to 30 minutes after cessation, and a temporary relief of depression symptoms (Laske et al. 2010). It is possible, however, that the temporary increase in BDNF is enough to initiate long-term neuronal changes. During exercise, a metabolite called β-hydroxybutyrate (BHB) is synthesized, and in turn, BHB increases production of BDNF which can then exert its neuroplastic and protective effects. The molecular and cellular effects of depression and exercise oppose one another through similar mechanisms mediated by BDNF in the same brain regions (i.e., hippocampus and pre-frontal cortex). Similarly, exposure to music has shown to increase available levels of BDNF in the hippocampus, and has been suggested as a possible treatment for psychiatric and neuronal disorders (Angelucci et al. 2007a, Angelucci et al. 2007b). As exercise and music have been shown to reduce depression, some underlying mechanisms may similarly reduce design fixation.

Applied to design fixation

While operating at a different time scale from overcoming depression, physical exercise and 'happy' music (i.e., music that elicits a positive affect and high arousal) have been observed to increase creativity. Exercise has been shown to improve various measures of cognitive performance by affecting the dorsolateral prefrontal cortex, the area of the brain often attributed to executive functioning and higher-order thinking (Yanagisawa et al. 2010). By interfering with intrusive thoughts, a focus on exercise may not only shift focus from fixation, but also work to increase creativity in other ways (Blanchette et al. 2005).

Opezzo & Schwartz (2014) conducted four experiments to study the effect of mild exercise (walking) on divergent and convergent creativity. Divergent thinking, or generating multiple ideas, was measured using the Alternate Uses Test (AUT), which asks participants to identify uses for common objects, e.g., a button. Convergent thinking was measured using the compound remote associates test, which asks participants to identify a single word that combines with each of three words. For example, given the words “cottage—Swiss—cake,” an answer is “cheese.” Opezzo & Schwartz (2014) found that walking improves AUT performance while walking and a little after walking. Walking on a treadmill increased 81% of participants' creativity on divergent thinking, but only 23% of participants' scores on convergent thinking, compared to performance while seated. They also tested the effect on creative analogy generation of walking outdoors, walking indoors on a treadmill, and outdoor stimulation (being rolled outside in a wheelchair). The authors found that walking outdoors led to the most novel and best generation of analogies, and conclude that walking "opens up the free flow of ideas".

However, Colzato et al. (2013) found that "acute moderate and intense physical exercise" interfered with divergent thinking in both athletes and non-athletes. Regarding convergent tasks, they found that non-athletes' performance decreased significantly, while athletes' performance improved. Further understanding the difference between what may be useful for overcoming depression versus design fixation could potentially inform interventions for both.

Ritter & Ferguson (2017) tested the effect on convergent and divergent creativity of listening to four classical music excerpts of different arousal (high/low) and valence (positive/negative) compared to a silent condition. They found improved divergent creativity in participants who listened to 'happy' (high arousal, positive valence) music than those in the silence condition, and no effect for convergent creativity. They found no improvement in creative performance when listening to music that is 'calm' (low arousal, positive valence), 'sad' (low arousal, negative valence), and 'anxious' (high arousal, negative valence).

4. EXISTING LINKS

Examining methods to overcome design fixation and psychiatric disorders, in particular depression, reveals valuable links between them.

Reframing the problem promises to be a highly effective method of managing design fixation, especially as the original framing of the problem may be a cause of design fixation (Ostafichuk et al. 2011). However, actually reframing is perhaps more easily said than done. Asking one to simply reframe a problem is somewhat dismissive of the fact that the current framing of the problem is causing the issue to be overcome. Therefore, tools to illuminate previously unseen components of the problem are required. This is where Socratic questioning may be useful. Similar to its use in cognitive restructuring, the Socratic method may help a designer probe what they believe to be true, debunk false assumptions, and delve into new aspects of the task. In fact, many of the methods used in the third step (evaluation) of cognitive restructuring may be useful in this endeavor. This endeavor is further supported by Beck & Emery's (1985) description of cognitive restructuring that involves critical questioning of how the current problem is being viewed. Beyond Socratic questioning, additional techniques such as decentering and reattribution can also be used towards reframing problems.

Moreover, incubation and distraction may be similarly linked. When using strategic attentional control, e.g., ATT or other less formal versions of distraction, one can purposefully take time away from the original task or design problem. When a designer uses distraction or ATT, they are taking their focus away from the design problem to think about something unrelated for some time, ideally, upwards of 10 minutes. While they are focusing elsewhere, perhaps the same mechanisms at work in incubation are taking place, allowing for design fixation to be overcome. Similarly, Beck & Emery (1985) propose the turn-off technique to help overcome anxiety, whereby a distracting stimulus or task is presented to redirect focus from distressing thoughts. The links between CT, ATT, and existing defixation methods suggest that some form of (focused) distraction and incubation is helpful when trying to shift focus to solve a problem.

5. CONCLUSION

The current paper briefly summarized a selection of design-defixation methods before exploring possible interventions based in cognitive therapy (CT) and other therapeutic methods to supplement existing defixation tools. In this exploration, several links begin to appear between analogous mitigation strategies. This supports the potential of exploring disciplines outside of engineering that offer formal protocols and techniques to supplement existing defixation methods. Conversely, design-defixation methods may also be applicable to reduce maladaptive thoughts for mental health.

Although the choice of depression as an analogy for design fixation was initially by chance, further exploring the parallels between the two consolidates many separate lines of inquiry into improving creativity. For example, depression often involves excessive rumination on the same unproductive thoughts. Similarly, design fixation has been described as being in a mental rut. Thus, it becomes less surprising that many activities prescribed for lifting depression (e.g., music and physical exercise) have also shown promise for breaking out of mental ruts.

The current paper represents an initial effort to bridge strategies between design-defixation and psychological therapeutic methods (summarized in Appendix B). Noteworthy is that psychological interventions have been rigorously tested and documented, a great benefit for other disciplines looking to apply their insights. Many creative and important parts of engineering design are still performed by humans, who are subject to individual cognitive strengths and limitations. Thus, the transfer of relevant theories and results from psychological research have the potential to fundamentally advance creative productivity in engineering design.

Future work aims to further study the reported connections between psychological therapeutic and design defixation methods. Developing studies that measure ideation and creativity while ensuring methodological rigor is challenging. A key consideration is the availability of participants, i.e., with appropriate engineering and/or design expertise, in sufficiently large sample sizes. Another consideration is to balance the experimental task with participant motivation. The creative nature of design tasks requires much more time and effort for ideation than most surveys or quantitative tasks. For example, simply asking participants to come up with as many solutions as they can to a design problem before reaching an impasse or block requires fairly substantial mental effort. Asking them to undergo potentially onerous defixation techniques to move past this impasse requires further effort, expenditure of which is difficult to confirm. Together, these considerations point to a great need for thoughtful research design methods.

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APPENDIX A: Types of Questions Used in Cognitive Therapy (CT) Applied to Address Design Fixation

Types of questions used in CT, as described by James et al. (2010)	Questions as expressed by James et al. (2010)	Questions applied to address design fixation
"Question stem: *Beliefs can be elicited by providing the first half of a sentence."*	• "If you don't work hard then…?" • "If you trust someone then…?" • "If I do a bad job…?"	• If concept A uses a different power source, then… • If a different configuration from Concept B is used, then…
"Queries: *Used to clear up misunderstandings and demonstrate active listening."*	• "Can you tell me what you mean by…?"	• Can you tell me why this problem is so hard to solve? • Can you tell me why this is something the solution must do? • Can you tell me why this is a necessary constraint?
"Appraisals: *To judge a client's qualities, success or needs."*	• "Are you satisfied with the way things turned out?" • "What can you learn from this experience?"	• What did you learn from the failure of this concept? • What requirements of problem C did this (failed) concept meet?
"Probe questions: *These are used to follow-up on answers of general questions with the aim of eliciting more detailed information and checking that the initial response was correct."*	• "What is the worst that could have happened if you'd felt more anxious?"	• Where else can you find the required information that you haven't been able to get from your original (but not only possible) source?
"Re-contextualizing: *Enables negative memories to be placed in their contexts of time and place. The contextual information provides patients with cues to aid them to recall facts about past events that can aid in the development of alternative perspectives."*	• "You feel guilty for leaving your husband after he was convicted for the assault. So did you just leave on a whim or were there events/circumstances that caused you to leave him? Let's list some of these reasons."	• You believe that the concept without feature D failed because you neglected to include feature D again. What are other reasons that concept might have failed?
"Lateral: *Examination of day-to-day features, looking for common themes that produce and maintain a client's difficulties."*	• "Looking at your diaries you have completed over the week regarding your aggression, are there any common themes that trigger your anger?"	• Looking at all your ideas, what are the common themes?
"Vertical: *Examination of historical patterns and cycles, looking for common themes that produce and maintain a client's difficulties.*"	• "Have you thought you were a failure at any other time in your life?"	• When do you tend to be the most unable to develop new concepts?
"Suggesting the opposite: *A technique that is useful to help stimulate a client's awareness of "Negative automatic thoughts" is to suggest something that is the opposite of what their response or thinking might be. This stimulates an "oh no, not like that at all. . ." response.*	• "Was it your actual intention to upset your child and make her cry?"	• Does a failed concept make you a bad designer? • Is there absolutely no other way of expressing this design need? • Is there no other source of information that could provide another way of approaching this problem?

APPENDIX B: Summary of Fixation Interventions from Cognitive Therapy (CT)

Technique	Methods	Effects	Applied to design fixation
Cognitive restructuring	A CT process to identify and correct cognitive distortions. This involves five steps: 1) identify the target thought, 2) monitor it, 3) evaluate it, 4) elicit rational alternatives, and 5) reappraise the target thought.	The target thought/problem is reframed in a more logical and objective perspective.	Drawing a parallel between depression or distorted thoughts to design fixation wherein target thoughts are a designer's self-imposed requirements or example fixation. This technique is used to rationally evaluate the problem that the designer is solving.
Socratic questioning	Used in cognitive restructuring and other CT techniques to question target thoughts. In dialogue format, this technique questions all underlying assumptions and knowledge of and surrounding the target idea(s). This is a technique that can be used to reframe the problem.	A more thorough understanding of the problem and what the solver thinks about it (i.e., self-awareness).	This can be used to probe potential solutions and clarify the solution space towards a more coherent space search. May bring focus to components and concepts being used in problem-solving.
Downward arrow technique / Five whys	Used to clarify underlying fears / delve into the hierarchy of problem-solving by asking "why" iteratively when attempting to find the root cause of a problem. Often in dialogue format.	Uncovering the root cause of a problem, and often helps to reframe what the problem really is. Clarifies the initial or unspoken assumptions.	Can be used to probe the root cause of a design problem to reframe it. Can open up new avenues of solution space based on the hierarchies of problem-solving.
Exposure-response prevention (ERP)	Patients are exposed (often, *in vivo*) to the thing that causes stress, anxiety or fear. Used in the treatment of Obsessive Compulsive Disorder (OCD), eating disorders and phobias.	Decreased fear/anxiety effects of a target.	Reducing self-imposed limits on solution space searches due to habit, fear or anxiety; possible habitual use and/or irrational avoidance of certain domains/solutions.
Focused distraction	Purposeful attentional shifts used to direct mental workload to some other task. Upon other task completion, return to the original task. ATT is one formalized method of this technique. Focused distraction is used in coaching, education, and obsessive/phobic disorders.	Redirects conscious attention and workload away from the problem. Potentially allows for incubation effects to take place.	Drawing a parallel between design fixation and self-focused attention, using focused distraction (e.g., ATT) to alter mental workload temporarily.