A Step Beyond to Overcome Design Fixation: A Design-by-Analogy Approach

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Design fixation is a phenomenon that negatively impacts design outcomes, especially when it occurs during the ideation stage of a design process. This study expands our understanding of design fixation by presenting a review of de-fixation approaches, as well as metrics employed to understand and account for design fixation. The study then explores the relevant ideation approach of Design-by-Analogy (DbA) to overcome design fixation, with a fixation experiment of 73 knowledge-domain experts. The study provides a design fixation framework and constitutes a genuine contribution to effectively identify approaches to mitigate design fixation in a wide range of design problems.

Introduction

A number of methods have been developed to combat design fixation. Design by Analogy (DbA) has shown effectiveness in generating novel and high quality ideas, as well as reducing design fixation. The present study explores a number of research questions related to design fixation: (1) have the approaches for addressing fixation been presented in a cumulative way, integrated to understand challenges and implications in different fields (2) are there comprehensive metrics to understand and account for fixation;

Design Computing and Cognition DCC'14. J.S. Gero (ed), pp. xx-yy. © Springer 2014

(3) can a better understanding of DbA approaches be developed to manage design fixation analyzing fixation present in transactional problems; and (4) does a particular semantic DbA approach, provide domain experts the ability to overcome fixation for transactional problems?

Background and Context

Design fixation

Definitions of fixation differ with context of design objectives, human activity, or field of knowledge. Examples include memory fixation, problem solving fixation [1], cognitive fixation [2], conceptual fixation, knowledge fixation, functional fixation, operational fixation [3], design fixation [4], and [5].

Design fixation is described as the inability to solve design problems by: employing a familiar method ignoring better ones, self-imposing constraints [6], or limiting the space of solutions by means of developing variants [5], [1], and [7]. A number of causes can contribute to fixation [8] and [9]: expertise [8], designer's unfamiliarity with principles of a discipline or domain knowledge [9], and [10], personality types [11], unawareness of technological advances, or conformity due to proficiency in the methods and supporting technologies of an existing solution [1].

During the design process, design fixation can emerge when example solutions are presented [12], [13], [14], [8], [15], and [16], when a considerable amount of resources are invested on a potential solution [17], when there are weak or ill-defined problem connections either internally (within elements of the problem) or externally (between the problem and other problems) [18], and when there are more vertical (refined version of same idea) than lateral transformations (moving from one idea to another) [19].

Design fixation research is critical due to its impact on design outcomes and the potential, if mitigated, to improve designers' abilities to generate innovative solutions. Studies from design, engineering, and cognitive science, provide findings across a number of fields, as described below.

Ideation approaches to overcome fixation

Design process success depends highly on ideation stage results [21], [22]. Extensive studies have focused on the improvement of metrics to evaluate ideation processes and associated mechanisms: quality, quantity, novelty (originality), workability (usefulness), relevance, thoroughness (feasibility), variety, and breath [18], [23], [24], [25], [26], [27], [28], [29], [30], and [31]. Some metrics consider design fixation in a quantitative way; others as a qualitative incidental discovery, measured indirectly through other ideation metrics.

Table 1. Cumulative framework of approaches to overcome fixation

Trigger or Source	Implementation method	Method/Technique/Approach	Reference(s)
Intrinsic	Individual Level	Problem Re-representation/ reframing	[21]; [8]; [32]; [33]
		Enabling Incubation	[34]; [35]; [36]; [37]; [38]; [2]; [15]; [39]; [40]; [41]
	Group Level	Diversify personality type	[8]; [11]
	Individual ∩ Group	Level of expertise or domain knowledge	[42], [10], [9], [39], [43], [44], [45]
Extrinsic	Individual Level	Abstract formulation of the problem	[33]
		Use of C-K expansive examples	[12]
		pictorial examples	[46]; [13]; [9]; [16]; [47]
		audio recorded examples	[49]; [50]
		Provide analogies	[48]; [15]
		Provide analogies along with open design goals	[51]; [52]; [16]
		Use of design heuristics	[53]
		Idea generation enabled with computational tools	[54]; [8]; [18]
		Graphical representations	[13]; [55]; [47]
		Case-Based Reasoning and Case-Based Design	[9];[88]; [89]
		Use word graphs	[56]
		word trees	[57]; [58]; [50]
	Group Level	Electronic Brainstorming (EBS)	[49]; [50]
		6-3-5/C-Sketch	[43]; [40]; [59]
	Individual ∩ Group	Provide de-fixation instructions	[13]
		Develop physical artifacts (prototyping)	[13]; [17]; [60]; [61]; [62]
		SCAMPER	[63]; [40]; [39]
		Provide a creative design environment	[64]; [39]
		Perform product dissection	[65]
		Develop functional modeling	[66]; [8]
Intrinsic ∩ Extrinsic	Group Level	Translating the design process into a Linkography	[67]
Intrinsic ∩ Extrinsic	Individual ∩ Group	TRIZ	[68]
		Conduct a morphological analysis	[71]

Recent ideation studies show some degree of effectiveness in overcoming design fixation. Based on this information, Table 1 is developed as a framework to understand, cumulatively, approaches to overcome design fixation. The table is defined by means of two parameters:

- *Trigger or source* provided by the method, which is divided into Intrinsic and Extrinsic.
- *Implementation method* corresponds to the number of designers involved, either Individual or a Group.

There are methods that can be found at the intersection of the parameters presented, for example: functional analysis is an extrinsic method that can be applied individually or as a group.

Intrinsic approaches

Intrinsic approaches are techniques and methods where ideas are triggered from intuition or previous experience. Problem Re-representation or re-framing is a method that increases retrieval cues for analogical inspiration or expands design space exploration [21], [8], [32], and [33]. Incubation focuses on disconnecting from the problem by taking a break or performing a non-related task, to access other critical information where insightful ideas may emerge and enabling development of novel or original solutions [34], [35], [36], [37], [38], [2], [15], [39], [40], and [41].

At the Group level, Diversify personality type relates to the way people prefer to interact with others. This has been found to have an impact in design activities. For example, extroverted persons get more involved in dissection activities that have the potential to increase creativity [8] and [11]. Level of expertise or domain knowledge is at the intersection of individual and group level. This attribute emerges with designer's immediate knowledge, and can be expanded when working in teams, by using distant and/or different domain knowledge due to interactions with others [42], [10], [9], and [39]. However, some results indicate that novices generate more original concepts [43], while others show that experts consider details in their solutions due to a more evident association between problem and previous knowledge [44]. Due to prior exposition to a wide range of problems, situations and solutions [9], Experts have the ability to frame and break down a problem into more manageable parts [42], and [10], to work with incomplete or ill-defined problems [45], to identify relevant information, patterns and principles in complex design problems [10].

Extrinsic approaches

Extrinsic approaches are techniques and methods that make use of heuristics, prompts or with stimulus/assistance external to the designer. Abstract formulation of the problem promotes divergent thinking processes and generation of original ideas [33]. Another set of approaches correspond to the use of examples: C-K expansive examples allow exploration of knowledge beyond baseline [12], Pictorial examples allows designers to consider additional design information without constraining the design [46], [13], [9], [16], and [47], audio recorded examples enable retrieval of long-term memory concepts and concepts distantly associated, showing a positive impact on the number of original ideas generated [49], and [50].

A third set of approaches provide analogies that assist in restructuring the problem and triggering new clues to developed solutions [48], [15]. In addition, open design goals may influence cognitive processes in filtering information that will be then incorporated in the concept solutions increasing originality [51], [52], and [16]. Design heuristics promote divergent thinking by providing multiple sequential and/or systematic ways to approach the problem and generate novel and original solutions [53]. Idea generation enabled with computational tools allows alternating among types of problem representation and providing semantic or visual stimulus that will generate more productive ideas [54], [8], and [18]. Graphical representations offer a cognitive structure by means of external representation which highlights design complexity, condenses information and enables lateral transformations [13], [55], and [47].

Case based reasoning (CBR) and case-based design, which is the application of CBR to design, have roots in analogy reasoning by learning from experience. [9], [88], and [89]. CBR is used in Artificial Intelligence (AI) to contrast existing experiences/solutions/cases with new unsolved problems to find similarities and extend existing solutions to those new problems. Word graphs [56] and Word trees [57], [58], [50] provide a synergic combination of analogies, semantic and graphical information, computational tools and graphical representations that generate synergic results.

At the Group level, Electronic Brainstorming (EBS) enables interaction between members by a computer interface that prompts sets of ideas for overcoming production blocking [49] and [50]. 6-3-5/C-Sketch combines "use of examples," "use of design heuristics" and "use of graphical representations" that provide a sequential structure with visual and textual information [43], [40], and [59].

Table 1 considers six approaches at the intersection of individual and group levels: Providing de-fixation instructions makes designers aware of features/elements that should be avoided, overcoming repeating ideas and producing novel ideas [13]. Development of physical artifacts deals with design complexity (mental load). These models represent mental concepts as well as identify and manage fixation features [13], [17], [60], and [61]. However, introducing critical feedback during concept generation with prototyping may increase design fixation [62]. SCAMPER is a set of seven brainstorming operator categories that allow problem reframing and increase creativity through the use of analogies and metaphors that expand the design space [63], [40], and [39]. A creative design environment is considered an approach to overcome fixation since designers may be motivated by a nurturing and encouraging environment [64], and [39]. Product dissection allows "examination, study, capture, and modification of existing products." The method improves form and function understanding to develop new and different ideas [65]. Functional modeling enables functionality representation, to explore alternative means to link customer needs with product function, thus generating novel solution approaches [66], and [8].

Two sets of methods are at the intersection of *source* possible levels. At the group level, Linkography translates design process into graphs that represent the designers' cognitive activities [67]. At the intersection of *implementation method* two approaches are: TRIZ, which facilitates solutions by matching contradictions in design problems to design parameters and fundamental principles [68]. A study comparing graphical representations (sketching), control, and TRIZ showed that TRIZ was best in enhancing novelty [71], [75]. Morphological analysis enables generation of new solutions by combining different elements recorded in a matrix of functions versus solution principles per function [71].

The cumulative information presented above provides a better understanding of current approaches as well as implicit opportunities for integration to evaluate possible applications. The presented classification implies the location of new approaches and possible outcomes.

Existing design fixation metrics

This section investigates existing metrics to assess fixation applicable to a broad spectrum of design problems ranging from service to products.

Direct Metrics

These methods inform a designer when fixation is happening and provide a crisp range of understanding for the concept of fixation. Table 2 shows the proposed classification for direct metrics found in the literature. These definitions are coincident to the fixation definition in Section 2.1 and enable fixation identification and accountability.

Indirect Metrics

Indirect metrics estimate fixation through indicators, but are not explicitly measured (Table 3). These indicators gauge if a designer is fixated, but do not provide additional information to validate the result.

Table 2. Direct metrics classification

Class	Metric(s)	Author(s)
Repeated Features	Calculation of fixation percentage. Lower values indicate non-fixated designs $\%\ Fixation: \frac{\#\ of\ similar\ features}{number\ of\ questions\ rated\ by\ the\ coders\ for\ each\ design}$	[11]
	Comparison of the number and percentage of features included in solution to a provided example	[8], [9]
	Obtaining low values for both variety and novelty metrics: $Novelty=1\text{-}frequency=1\text{-}\frac{number\ of\ ideas\ in\ a\ bin}{total\ number\ of\ ideas}$ $Variety=\frac{number\ of\ bins\ a\ participant's idea\ occupy}{total\ number\ of\ bins}$	[72]
	Measurement of functional fixation through dependent measures: (1) frequency of a given functional category at participant level, (2) number of functionally distinct designs, and (3) novelty* that measures solution uniqueness $^{*}Novelty=1\text{-}\frac{\#\ of\ functionally\ similar\ designs\ generated\ by\ other\ subjects}{total\ \#\ of\ designs\ for\ all\ subjects}$	[16]
	Originality score (at feature level) and technical feasibility of solutions from a score table. Originality evaluated after comparing features in designs with standard elements. Higher design feasibility corresponds to higher fixation	[43]
	Evaluation of similarity between design brief of the project and the proposed solutions	[62]
Non-redundant ideas	Correlation of the number of non-redundant ideas generated with the total number of unique ideas generated	[50]
	Presence of both low quantity and originality in generated solution. Originality is defined as statistical infrequency of a particular solution, which is a percentage from 0 to 1	[12]

Table 3. Direct metrics classification

Class	Metric(s)	Author(s)
Self-assessment	Commitment to an idea via Self-assessment. Surveys ask about perception of fixation reduction, generation of unexpected ideas and workflow improvement	[56]
Design movements	Linkography and Shannon's entropy principle – analyze all possible moves on graph and when moves are interconnected, the ideas are convergent and might be a sign of fixation	[67]
	Goel's type of transformations: vertical and lateral [19]. If more lateral than vertical, fixation can be prevented	[55]
Improvement of a response	Calculation of fixation effects for Remote Associates Test (RAT) subtracting the number of problems solved correctly between fixating and non-fixating stimuli conditions.	[73], [51]
Negative features	Assignation of a discrete value that ranged from 0 to 10 that corresponds to the number of neutral and negative fixation features that were found at given check-in periods	[74]
	Fixation identification as a focus in external features (form) and lower variety	[65]

Design-by-Analogy (DbA) Method

We explore a DbA approach due to its relevance, effectiveness and its potential to have synergic results when integrated with other approaches.

There is evidence that design solutions can be found or adapted from pre-existing systems or solutions from other domains [75], [71] for example: astronauts' vortex cooling systems were later adapted as a means to mold and cool glass bottles [76]. Inspiration from analogous domains can be achieved by associations between shared characteristics, attributes, properties, functions, or purposes [77], [78]. Once an association among a design problem and a solution in another domain is established, a solution to the design problem can be developed [42], [79], [80], [57], and [81].

WordTree [57], [58] and Idea Space System (ISS) [82], [56] are two DbA methods successfully applied in engineering and architecture. These two methods share principles and are based on semantic transformation of textual representations of design problems by means of Princeton's WordNet or VisualTheasaurus which is a visual display of the WordNet database. Both methods enable re-representation of the problem and expansion of solution space due to new semantic associations, finding and exploring potential analogies and analogous domains [57] [58], [82], [56], [83], and [15]. ISS uses a drawing table, a pen that records textual descriptions, sketches, as well as images; and a vertical screen that display wordtrees from WordNet. Using the WordTree method, a designer constructs a diagram of "key problem descriptors (KPDs)," focusing on key functions and customer needs of the given design problem [58]. KPDs are then placed in a tree diagram and semantically re-represented by hypernyms and troponyms selected from WordNet. The WordTree Diagram facilitates associations; therefore, analogies and/or analogous domains can be identified. All analogies, analogous domains and new problem statements can then be used to enrich group idea generation.

Transactional and Product Design Problems

Product design results in tangible artifacts, while transactional design emerges as "Services," virtual products of an intangible nature. Shostack defines services as acts that only exist in time [90]. Vermeulen notes features that differentiate services from products: intangibility, simultaneity of production and consumption, heterogeneity and perishability [91].

Currently, services and products are interconnected to varying degrees and may be considered as part of a continuum. This interconnection implies the potential of tools and methods for conceptual design from engineering and architecture can be transferred to transactional fields to assist idea generation and manage design fixation. It has been stated that early stage of development for services is no different than for physical products and that it is at the detailed design phase where the methods diverge [92], which supports the transferability of design methods between domains.

Experimental Method

Seventy-three transactional process experts were recruited from a professional development program in Mexico. Participants were from a variety of disciplines and involved 22 product and 14 service companies. Domain knowledge expertise was based on professional background and work role.

A transactional design problem was adopted from a previous study [27]: "Reduce overdue accounts/unpaid credits".

The experiment included a control and experimental treatment, and two phases (Table 4). The control did not specify a method (No Technique – NT) for either phase. Phase I of the Experimental treatment was the same as NT, and Phase II used a DbA method (With Technique – WT). Phase I and phase II were held with two days in between, with the same design problem in both. Groups were distributed by background, gender, and other demographics.

Table 4. Experiment phases and treatments

Treatment	Phase I	Phase II	Sample Size	Gender (Female/Male)
Control	NT	NT	36	11 / 25
Experimental	NT	WT	37	12 / 25

In all phases, participants were asked to individually create as many solutions for the transactional problem as possible, recording solutions as text and/or sketch/diagrams. In Phase I, all participants were given 15 minutes to generate solutions using intuition alone (Figure 1).

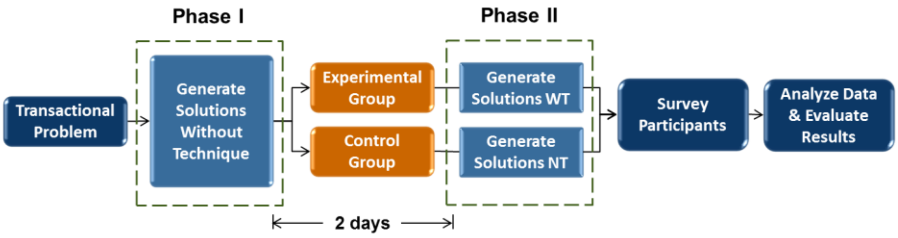

Figure 1. Experimental execution diagram

For phase II, participants were divided into two groups, NT and WT, in separate rooms. NT participants were asked to continue generating solutions without a specific method for 15 minutes. WT participants were given a 15 minute tutorial of the WordTree DbA method [25] and WordTree software (Thinkmap's Visualthesaurus©). Each participant was provided with a computer with Thinkmap's Visualthesaurus©. Relevant information and graphical associations between words were displayed by the software. Participants were then asked to generate solutions to the transactional design problem using the method and software tools for 15 minutes.

During phase II, WT participants were asked to select words that re-represented the design problem. The goal was to understand semantic retrieval from the participants' memories that allowed them to switch domains while developing analogous problem statements. Participants were required to list all alternative solutions they developed after extracting useful information form the provided software tools.

At the end of both phases, listed ideas were collected, coded, analyzed and rated by two domain knowledge expert raters. Participants were also asked to fill out a survey after completing each phase.

Analysis

The ideas were sorted into bins of similar ideas. Coding and analyses establish connections to the comprehensive map of approaches to overcome fixation (Section 2.2) as well as fixation's existent metrics (Section 2.3).

Accounting for Fixation

To compare the results of present study with existing ones, we present our approach that captures the semantic nature of transactional problems. Design fixation was assessed using the procedure outlined by Linsey (2010) and Viswanathan (2012). The proposed metric elaborates what a repeated idea is for the study and, instead of reporting an absolute value, contrasts this value against the total number of ideas developed. This approach provides a sense of the intensity of design fixation.

A design fixation definition is implemented as shown in Eq. 1:

$$Fixation = \frac{Total\ \#\ of\ repeated\ ideas}{Total\ \#\ of\ generated\ ideas} = \frac{Q_R}{Q_{Total}} = \frac{R_w + R_B}{Q_{Total}} \quad (1)$$

Quantity of ideas

Three representations are defined: (1) Quantity of total ideas generated (Q_{Total}), (2) Quantity of repeated ideas (Q_R), where a repeated idea occurs when a participant develops a slight variation of a previous idea, and (3) Quantity of Non-repeated ideas (Q_{NR}), which corresponds to the remaining number of Q_{Total} once repeated ideas have been removed.

$$Q_{Total} = \sum all\ ideas\ generated = Q_R + Q_{NR} \qquad (2)$$

Eq. 2 shows that Q_{Total} can be expressed as the summation of all ideas generated at different levels such as by phase (I, II), experimental group (WT, NT), and participant. Q_{Total} can alternatively be defined as the addition of its two sub-components: Q_{NR} and Q_R.

Two phases of the experiment offer two sources for repeated ideas (Q_R):

- Repeated ideas within a phase (R_W): all repeated ideas across all participants for which frequency (F) is greater than 1.

  $$R_{W_i} = \sum_{j=1}^{b} \sum_{k=1}^{n} F_{ijk} - 1 \quad \forall\ F_{ijk} > 1 \qquad (3)$$

  where F_{ijk}=frequency of repeated ideas for the ith phase, jth bin, and kth participant; i=phase number (1, 2); b= number of bins (117); n= number of participants. A unit is subtracted from F_{ijk} to maintain accountability of the total of ideas generated.

- Repeated ideas between phases (R_B): all ideas that were generated in Phase I that reappear in phase II at bin and participant levels (Eq. 4).

  $$R_B = \sum_{j=1}^{b} \sum_{k=1}^{n} F_{2jk} \quad \forall\ F_{1jk} > 1 \ \text{ AND } \ F_{2jk} > 0 \qquad (4)$$

  where F_{ijk}=frequency of repeated ideas for the ith phase, jth bin, and kth participant; i=phase number (1, 2); b= number of bins (117); n= number of participants.

Results

Statistical data validation

A retrospective power study was performed to validate power of statistical tests and assumptions [84]. For t-tests, power factors were: significance level α=0.05; variability and minimum difference depending on the metric being evaluated; and actual sample sizes of the study (NT=36, WT=37). All power values were higher than 91% for evaluated metrics, corresponding to a suitable power to perform statistical analysis. Normality of data was evaluated and met using Anderson Darling's Normality Test.

Quantity of ideation

To calculate fixation (Section 4.1), we first determined Q_{Total}, Q_R and Q_{NR}. Table 5 presents quantity of ideas across phases and group levels. Q_{Total} corresponds to 1,133 ideas, including 316 Q_R ideas, and 817 Q_{NR} ideas.

Table 5. Quantity of generated ideas, repeated ideas, and non-repeated ideas

Q_{Total}			
Control Group		Experimental Group	
Ph I	*Ph II*	*Ph I*	*Ph II*
326	328	286	193
t-value= 0.08, *p*-value=0.940		*t*-value=-3.37, *p*-value=0.002	
Anova Ph I		*F*=1.82, p-value=0.182	

Q_R			
Control Group		Experimental Group	
Ph I	*Ph II*	*Ph I*	*Ph II*
45	172	47	52
t-value=6.63 *p*-value=0.000		*t*-value=0.45 *p*-value=0.658	
Anova Ph I		*F=0.00 p-value=0.953*	

\+

Q_{NR}			
Control Group		Experimental Group	
Ph I	*Ph II*	*Ph I*	*Ph II*
281	156	239	141
t-value = -4.97 *p*-value = 0.000		*t*-value = -4.19 *p*-value= 0.000	
Anova Ph I		*F=2.75 p-value=0.102*	

ANOVA (last row Table 5) shows no statistically significant difference in the quantity of ideas generated in phase I for both experimental and control groups. This result is expected because phase I corresponds to an equivalent non-assisted scenario for both groups.

A paired t-test comparing phase I and II for the control group's Q_{Total} shows no statistically significant difference, which is expected because phase II is also non-assisted. A paired t-test comparing phase I and II for the experimental group's Q_{Total} shows a statistically significant difference, consistent with previous cognitive studies where intervention scenarios add significant load due to cognitive processing [85], [86], and [16].

For Q_R, a paired t-test comparing phase I and II for the control and experimental groups showed a statistically significant difference in quantity of ideas of control group, which is consistent with literature that design fixation in the form of repeated ideas can be higher if no method is employed [50], [11], and [20].

Finally, for Q_{NR}, a paired t-test comparing phase I and II for the control and experimental groups shows a statistical significant difference in the quantity of ideas for both scenarios.

Table 6 summarizes the quantity of repeated ideas. An example of a repeated idea is "impose a penalty" and "make credit performance public." "Impose penalty" was a solution idea stated in phase I and then repeated in phase II by the same person (R_B). "Make credit performance public" was an idea stated by a participant more than once during a single phase (R_W).

Table 6. Repeated ideas by group, source and phase

Repeated ideas	WT (n=37)		NT (n=36)	
	Ph I	Ph II	Ph I	Ph II
Total R_W	47	24	45	40
Total R_B	0	28	0	132
TOTAL	**47**	**52**	**45**	**172**
Average	1.3	1.4	1.3	4.8

For the NT group, the quantity of R_W is almost the same for both phases, and there is a large quantity of R_B, that is, participants repeated ideas they created in phase I. The WT group reduced by half the number of repeated ideas within in phase II, and the number of ideas participants repeated from phase I was close to half. When studying the average of repeated ideas per participant, a distinctively different value exists from the control group, Phase II. The other three averages were almost identical.

Fixation

Table 7 shows the results of applying Eq. 1 to assess fixation in transactional design problem solving.

Table 7. Fixation (%) by Phases of both Groups

Group	***Experimental***		***Control***	
Phase	*Ph I*	*Ph II*	*Ph I*	*Ph II*
Fixation (%)	16.4%	26.9%	13.8%	52.4%

No statistically significant difference in the design fixation metric using a two sample t-test is found when comparing phase I of the experimental and control groups (t-value= 0.89, p-value=0.376). This result may indicate a base level of fixation for non-assisted scenarios. Table 7 shows that the fixation percentage is lower after applying the method (phase II), and a two sample t-test between phase II of the experimental and control groups shows a statistically significant difference in fixation (t-value=-4.33, p-value=0.000) between both groups.

Discussion and conclusions

The literature offers several overlapping metrics and indicators for fixation. Direct and indirect metrics were grouped in an attempt to unify metric criteria. A proposed fixation metric builds on previous work to include transactional problems. The results of this study of a transactional problem are comparable with the ones obtained for engineering and architecture, allowing possible generalization of conclusions.

In this study, there was a reduction in total number of ideas for the experimental group which is believed to be a reflection of the load that the applied method adds cognitively. However, analysis of the quantity of repeated ideas shows that the WordTree DbA Method helped overcome fixation to pre-developed solutions as compared to a control. The quantity of non-repeated ideas was reduced in phase II for both the control and experimental conditions, though this may be due to the fact that the experimental group was new to the method and software. More proficiency in the DbA method may increase the quantity of ideas, and merits further studies.

Differences in quantity were translated into fixation percentages revealing that there is a base level of fixation for non-assisted scenarios that remains statistically the same after applying the WordTree DbA Method, while for phase II of a non-assisted scenario, it doubles. These results highlight the efficiency of the WordTree DbA Method as utilized by design experts to effectively manage design fixation.

Would the fixation level during the ideation stage be significantly different using a DbA method compared with a non-assisted scenario? From the study results, there is evidence that in a non-assisted scenario, a significant portion of the allotted time was devoted to developing solutions that are not distinctive from each other (repeated production exceeded the non-repeated), while analogical transfer provided by the WordTree DbA Method enables problem re-representation, exploration of divergent words and effective space solution exploration to solve the problem.

The DbA method used here combines some previous approaches from the proposed cumulative framework to overcome design fixation that supports its strength and robustness. From Table 1, the studied DbA method incorporates elements from different categories. It includes: reframing, by characterizing the problem and problem re-representation. The two day break between phases served as an incubation period. It considers expertise that allowed working with incomplete information, framing the problem, identifying relevant information and developing more solutions. It provides and enables analogical exploration. It uses software tools that provide visual representation of the semantic cognitive process allowing problem and solution representation.

The positive results obtained with the experiment are not only aligned with existent research in design fixation, but also with reported results in the psychology field [87]. Leynes et al. (2008) found that fixation can be overcome in two ways: first with an incubation period of 72 hours, and the second (and closely related to our approach) by presenting alternative semantic information to participants. They found that block and unblock effects occur in different parts of the brain. The results of the present study align with this result because after the semantic stimulation and analogy exploration, the participants were able to overcome design fixation.

Acknowledgements

The authors wish to acknowledge the support provided by the ITESM-BMGI Lean Six Sigma Program and the SUTD-MIT International Design Centre (IDC, idc.sutd.edu.sg). Any opinions, findings, or recommendations are those of the authors and do not necessarily reflect the views of the sponsors.

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