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THE INS AND OUTS OF THE CONSTRAINT-CREATIVITY RELATIONSHIP

Marnina Eden Herrmann[1], Gabriela Goldschmidt[1],
Ella Miron-Spektor[2]

[1]Faculty of Architecture and Town Planning, Technion – The Israel Institute of Technology, Haifa, Israel
[2]Faculty of Industrial Engineering and Management, Technion – The Israel Institute of Technology, Haifa, Israel

Abstract: In today's increasingly complex world, designers and other practitioners are required to tackle problems creatively while adhering to an ever-growing list of constraints. Existing research on the constraint-creativity relationship reveals mixed findings, with some studies suggesting that constraints can hinder creativity, and others showing that constraints can enhance creativity. Most studies that look at this relationship examine the impact of the type or severity of the constraint on creativity leaving us with many questions about the less studied factors that can moderate this relationship. In our study 62 industrial engineering students completed a design-ideation task that measured the impact of constraints on creativity. Our data shows that self-imposed constraints are beneficial to creativity relative to external constraints, providing empirical evidence of the benefits of self-imposed constraints.

Keywords: *Creativity, Constraints, Design Process*

1. Introduction

In his book *What Designers Know,* the architect and scholar Bryan Lawson (2004) tells the story about his experience working on a hospital design that was exempt from fire regulations (as in this case, one government department could not regulate another). The fire officer at the time told him that his design was actually safer than it would have been had he followed current regulations to the letter of the law. Because of his familiarity with his discipline he was able to better constrain the scope of the project by making more appropriate decisions about the project's limitations and requirements than those writing the regulations.

Research has shown that constraints can both inhibit and enhance creativity depending on a wide variety of factors including (but not limited to) the type and severity of the constraint. Even looking at a specific constraint, for example time constraints, research often produces mixed findings with some results pointing to limited creativity and others pointing to increased creativity (Amabile, Hadley, & Kramer, 2002). These findings lead us to believe there are other forces at play that moderate the relationship between creativity and constraints. Lawson's experience illustrates one example of the inconsistent role constraints play in the design process as well as one possible explanation – constraint source. This paper discusses constraint source - self-imposed versus external as a variable in determining the strength of the constraint-creativity relationship. Self-imposed constraints refer to when an individual chooses his or her own limitations, consciously or unconsciously, when deciding upon the scope of a solution. External constraints on the other hand, are constraints that are imposed upon the individual from an outside source, for example, a manager, a client or governmental regulations. More specifically, we look at the impact of input constraints on creativity in a design ideation task, comparing designs that were the result of a constrained design brief versus self-imposed constraints. As the above story demonstrates, by taking ownership of a project's constraints, rather than following those selected by an outside source one can come up with superior solutions. Our study provides empirical evidence of the impact of constraint source on the constraint-creativity relationship.

This research was a secondary analysis of another study testing whether constraints presented at a later stage in the design process help or hinder creativity relative to no constraints or to constraints presented at the beginning of the process. At the time of this analysis, our experiment showed no significant differences in novelty or usefulness for the three groups. Because of this, we decided to conduct a post-hoc analysis that examined creativity at a sketch level as opposed to a participant level, in order to take a closer look at how people responded to the task constraint.

2. Literature Review

In a world dominated by increased competition and complexity, creativity is becoming more and more important to economic success (Fraser, 2007). Creativity, commonly defined as the force responsible for the creation of novel and useful solutions in any domain (e.g., Amabile, 1996) can help designers, engineers and managers to innovate, when faced with a wide variety of constraints such as: reduced costs, improved quality and satisfying the unique needs of each consumer. That said, the effects of constraints on creativity are unclear. Some research suggests that by limiting one's options, constraints force one off the path of least resistance (Ward, 1994), and encourage increased creativity. Other studies suggest that constraints can hinder a person's ability to be creative by limiting their options (Amabile et al., 2002; Doboli & Umbarkar, 2014). Most often though, the effect of constraints can go both ways and the key is to manage constraints in such a way that they can properly provide structure to the problem without limiting creativity (Stacey & Eckert, 2010).

2.1. Input Constraints and Creativity

The mixed findings in the existing research are in part due to the wide range of constraints that exist and the lack of a cohesive operational definition in the research. As each study chooses to examine its assumptions using different parameters (Caniëls & Rietzschel, 2013), it makes it difficult to develop a cohesive theory on the constraint-creativity relationship. In our study we have chosen to look at the impact of input constraints, constraints which limit choice with regard to the creative problem itself such as resource constraints or thematic constraints (Joyce, 2009; Moreau & Dahl, 2005; Peterson et al., 2013; Savage, Miles, Moore, & Miles, 1998; Scopelliti, Cillo, Busacca, & Mazursky, 2014) as opposed to those that examine limitations of the designer or the context.

Existing research demonstrates that input constraints are often beneficial to creativity. For example, in their 1998 paper, Savage et al. look at the interaction of time constraints, structural constraints and financial constraints on design variability in a simple building design task. While overall the experiments show that as constraints increase variability goes down, the negative effect of the constraints is actually weakened in conditions that include the financial constraints. As suggested in the MIT Sloan Management Review, this could occur because those with an over abundance of resources often find themselves in a resource-driven mindset, focusing more on what they do and do not have, than on the problem at hand (Gibbert, Hoegl, & Välikangas, 2007). Additionally, resource scarcity has been shown to be positively correlated with creativity as it prevents functional fixedness, causing people to look beyond objects' traditional uses, thus leading to more creative solutions (Mehta & Zhu, 2015).

While there is plenty of evidence that points towards the positive impact of input constraints on creativity, this effect is limited. In fact, the relationship between constraints and creativity generally follows an inverted U-shaped curve where constraints are beneficial up until a certain point and then eventually become too restrictive thus reducing creativity (Joyce, 2009). Additionally, if the resources allotted to the task are not appropriate, they will not assist in reaching a creative outcome (Noguchi, 1999).

It is also interesting to note the effect of different types of input constraints on the design process itself (and thus the level of creativity). For example, financial constraints have been shown to elicit a top-down approach to constraint satisfaction, meaning one will come up with a solution and fit the constraints (in this case the available financial resources) to the solution. Material constraints on the other hand, elicit a bottom-up approach where materials are considered and a solution is designed that combines them. Generally, a bottom-up approach leads to a more novel solution whereas a top-down approach will lead to a more appropriate or useful solution (Scopelliti et al., 2014). Other studies show that it is not the type of constraint, but rather the severity of constraint that will direct a person to a specific approach. When a problem has both input restrictions and requirements (meaning one must exclude certain things in their design while including others) one tends to take a bottom-up approach where one focuses on the problem and builds a solution from there, but when there were either restrictions or requirements participants were able to find an existing solution and to apply the constraint to it (Moreau & Dahl, 2005). The idea that top-down and bottom-up processes affect creativity differently is the first hint that self-imposed constraints and constraints from an external source may have different effects as well.

2.2 Constraint Source and Creativity

While differences in constraint type and constraint severity can lead to top-down and bottom-up processes, taking constraint definition into ones own hands, rather than simply following given constraints, is sure to guarantee this differentiation. Sometimes referred to as enabling constraints, self-imposed constraints are constraints chosen by the individual in order to purposefully limit the problem space thus creating coherence in the creative output or discipline in the process (McDonnell, 2011). This concept is similar to what Donald Schön refers to as the process of imposing order on one's work which involves balancing the freedom to be creative with the need to adhere to limitations (1985). While these examples refer to a specific thought-out choice, sometimes these self-imposed constraints come from a subconscious place. For example, in Jazz improvisation we like to think of people as free to release a stream of creative consciousness, yet these seemingly random choices are generally a logical follow up to earlier choices based on the artist's tacit knowledge of his or her discipline (Johnson-Laird, 1988).

It is this tacit knowledge that provides another explanation for the effectiveness of self-imposed constraints at eliciting creative results. Generally speaking, those tasked to solve specific problems know more about how to solve them than those appointing them to the job. Architects for example, are often subject to working through a lot of bureaucratic red tape. Generally those writing the regulations are focused on being able to enforce rules and quantify results as opposed to best practices or encouraging creativity. Even worse is that these bureaucrats are not always experts in the fields that they are attempting to regulate, which can lead to inappropriate constraints (Lawson, 1975, 2004). Another factor to consider is that when constraints come from an external source they are much more likely to be inflexible and even when there is a possibility that they could be changed over time they are often taken as absolute (Onarheim, 2012). Self-imposed constraints on the other hand offer much more flexibility. Patricia Stokes goes even further with this idea of self-imposed constraints, explaining that selecting constraints is central to the creative process and that artistic freedom manifests in choosing of one's constraints (Stokes & Fisher, 2005). Stokes discusses that constraints both preclude and promote one's options and if it is the reliable and repetitive that get precluded, it follows naturally that the novel and original will be promoted (Stokes, 2001). Returning to the example of Jazz improvisation we see how a musician's choices constrain his or her future choices as each note precludes or promotes other notes from following what is being played in the present (Johnson-Laird, 1988).

Another important factor in the constraint-creativity relationship is motivation. Intrinsic motivation is seen as an important precursor to creativity and has been shown to mediate the relationship between constraints and creativity (Rosso, 2014). When constraints are viewed negatively they will inhibit intrinsic motivation. This is especially true of external constraints. More specifically, this happens when external constraints are seen as controlling, coercing someone into reaching a specific solution (Koestner, Ryan, Bernieri, & Holt, 1984). This is in line with self-determination theory, which (among other things) states that autonomy is an important contributor to intrinsic motivation. Efficacy alone is not enough to cause intrinsic motivation, one must also perceive one's own behaviour as self determined (Ryan & Deci, 2000). In fact, ownership of constraints is seen to play an important role in influencing creativity (Onarheim, 2012).

3. Methodology

This study is part of an on-going research project seeking to empirically study the effect of delayed constraints on creativity in design and problem-solving tasks. Three conditions (no constraints, constraints at the outset, delayed constraints) were assessed by manipulating the time at which constraints were introduced into a design ideation task adapted from Ronald Finke and associates (Finke, 1990).

3.1 Participants and Design

Participants (*N*=62, mean age = 25, 47% female) were undergraduate industrial engineering students who participated for class credit. Participants were assigned to one of three conditions: no constraints, constraints at the outset, and delayed constraints. All participants were given an illustrated list of components (see figure 1) to act as materials for their task, as well as sketching paper and drawing implements. Participants were instructed to spend ten minutes sketching ideas for a toy consisting of components from the list provided. Those in the no constraint condition were allowed to make use of all components in any amount and configuration. Those participants in the outset condition were told prior to starting the task to sketch ideas for a toy using a maximum of four components from the list. After five minutes of sketching without constraints, those in the delayed group were told that all future designs could consist of no more than four components. Once participants finished the design task they were asked to number their sketches in chronological order, answer demographic questions, and then were debriefed and dismissed. Participants submitted a total of 305 sketches (*M*= 5 sketches per person).

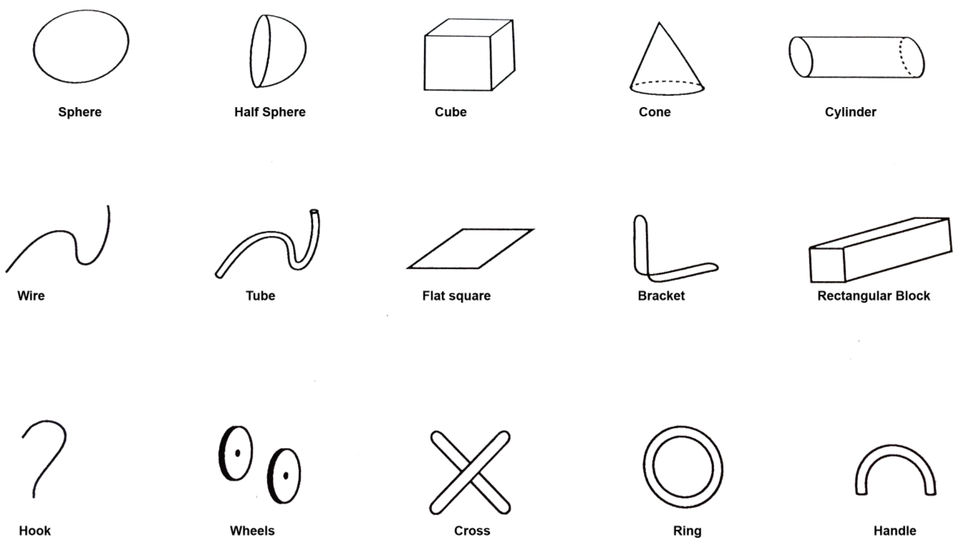

Figure 1. Parts used by Finke in imagery experiments. Source: Finke 1990, p.41

3.2 Measures

We used consensual assessment to measure product creativity (Amabile, 1982). Three independent judges who were blind to the experimental condition assessed each sketch on novelty and usefulness dimensions on a five-point Likert scale (1= not at all, 5= very much). Judges were trained prior to assessments in order to ensure consistency across submissions. Judges viewed sketches in a random order and were asked to rate them relative to one another as opposed to an absolute standard (Amabile, 1982). Sketches were rated and scores were calculated as the average of the three judges' ratings. Judges arrived at an inter-rater reliability score of ICC_2>0.69, which according to Cicchetti (1994) qualifies it as a sufficient level of reliability.

3.3 Control Variables

We collected data on demographics and prior experience working on similar tasks. These variables did not relate to the creativity dimensions and therefor were not included in the reported analysis.

4. Findings

4.1 Original Analysis

An ANOVA analysis examining the effect of experimental conditions on idea novelty and usefulness revealed insignificant differences across conditions. Because the constraint we employed in the experiment was to limit the number of parts one could use in their designs, upon encountering insignificant results we decided to check whether the constraint manipulation actually succeeded in limiting the parts used. A pairwise comparison revealed that while there was no significant difference between the numbers of parts in the two constraint conditions, there was a significant difference between the control group and each of the constraint conditions. The mean difference between the number of parts used in the control condition and the constraints at the start condition was 2.5, p=0.002. The mean difference between the number of parts used in the control condition and the delayed constraints condition was 2, p=0.008. As the delayed constraint condition included designs that were created both with and without constraints we decided to compare the number of parts used in sketches that were created with constraints and without. There was a significant difference in the number of parts used when no constraint was present M = 5.56, SD = 7.5 vs. when constraints were present M = 3.25, SD = .862, p=0.001. Additionally, rather than use four parts (which was the number closest to the average without constraints), when faced with constraints, participants seemed to constrain themselves more than necessary. These finding prompted us to take a closer look at the data and run our secondary analysis in order to determine if and how the number of parts used in a design had an effect on novelty and usefulness.

4.2 Post-hoc Analysis

The primary subject of this paper focuses on the results of the secondary analysis, which looked at the novelty and usefulness ratings of 305 sketches completed by the 62 participants. To control for the nested structure of our data the analysis was completed using a two-level hierarchical linear model in HLM7. There was a significant correlation between the number of parts used in a sketch and novelty (p=0.006) – so that the more parts that were used the more novel the design (coefficient = 0.035). On the other hand, there was no significant difference in novelty between those sketches that were completed with constraints in place and those without (see Table 1). Additionally, there was no correlation between the number of parts used in a sketch and usefulness. There was also no significant difference in usefulness between those sketches that were completed with constraints and those without (see Table 2).

Table 1. HLM2 for Novelty Scores of all sketches

	Coefficient	SE	*t*-ratio	Approx *d.f.*	p-value
for Total Parts	0.035452	0.012404	2.858	61	0.006
for Constraints	-0.131354	0.154111	-0.852	60	0.397

Table 2. HLM2 for Usefulness Scores of all sketches

	Coefficient	SE	*t*-ratio	Approx *d.f.*	p-value
for Total Parts	0.008747	0.006667	1.312	61	0.194
for Constraints	-0.030389	0.127420	-0.238	60	0.812

4.2.1 Analysis by the number of parts

On one hand whether or not constraints were present impacted the number of parts used in a design, and the number of parts used in a design was correlated with the level of novelty. On the other hand, there was no correlation between the presence of constraints and novelty. Due to this seeming contradiction we broke down the designs into groups according to how many parts were used in the design to see whether or not the presence of external constraints impacted novelty in a group of designs with a homogenous number of parts. In a majority of cases, there was no significant difference between the novelty of those designs that were created with constraints and those that were created without. There was one notable exception to this finding. The group of designs consisting of four parts (N=93) displayed highly significant (p=0.003) differences in novelty between those designs that were created under constraints (N=66) and those designs that were not (N=27) (see Table 3). Having external constraints hindered novelty (coefficient = -0.746). The group of designs consisting of four parts is unique in that it matched the number of parts one was restricted to using under the task's brief. This means that in the case of the designs in this group those designs that were born out of a no-constraint condition were all the result of a self-imposed constraint, whereas those in the constraint condition were adherents to the external constraint. Designs that made use of one, two or three parts whether they were in a constrained or unconstrained condition were all a result of a self-constrained process as in both cases the participant chose to limit him or herself further than the design brief required (see Table 3). There was no significant difference in usefulness scores for designs created with and without constraints for any number of parts.

Table 3. HLM2 for Novelty Scores (with and without constraints)

	Coefficient	SE	*t*-ratio	Approx *d.f.*	p-value
1 part	-0.665944	0.477432	-1.395	4	0.236
2 parts	0.142292	0.249958	0.569	28	0.574
3 parts	-0.112885	0.272898	-0.414	40	0.681
4 parts	-0.746323	0.239564	-3.115	45	0.003

Designs with five or more parts were not included in the analysis as the few that were created under constraints disregarded the constraint of limiting the design to four parts.

5. Discussion

The study's results showed that the number of parts used in a design was correlated with novelty such that the more parts used in a design the more novel it was. Additionally, we saw that whether or not the design was created as part of a constraint condition did not have an effect on the creativity of a design. However, when one looked at only those designs containing the number of parts specified in the constraint condition (four), constraints did impact novelty, such that those that used four parts because of constraints were less novel than those designs that used four parts by choice. Usefulness was not correlated with either the number of parts or constraints. These results provide us with evidence that the source of constraints does impact creativity.

Further proof of our proposed theory lies in the number of parts used by the individuals who received the constraints versus those who did not. Prior to receiving constraints an average of 5.56 parts were used whereas after an average of 3.25 parts were used. Rather than simply adhering to the constraints and using four parts, as specified, participants chose to constrain themselves more than necessary, thus removing the negative effects of the external constraints (there was no difference in creativity levels for 3-part sketches from constraint conditions and non-constraint conditions). Rather than take the constraint of four parts as is and fit the design to it, participants chose the number of parts that was most appropriate to their design idea. By constraining oneself more than required one is able to turn top-down constraints into a bottom-up process. This may not have been a conscious decision but as discussed above, when engaged in a task, tacit knowledge will often take over and drive one to constrain oneself in a way that benefits the creative process (Johnson-Laird, 1988).

While the existing research provides us with ample theories to support the idea that constraint source has an effect on the constraint-creativity relationship, thus far, the empirical evidence to support these claims has been lacking. The little evidence that is mentioned in the literature tends to be anecdotal. Through exploration of our data we provide empirical evidence that external constraints have a negative effect on novelty compared to the exact same constraint when self-imposed. Furthermore, the theories that discuss constraint source do not directly address the dichotomy between self-imposed and external constraints; rather they tend to focus on the benefits or disadvantage of one of the two. Our work highlights the contrast between these two constraint paradigms, thus contributing a holistic approach to the existing theory on constraint source.

5.1 Limitations and Future Research

Because this was a secondary analysis we were limited to the data gathered from our earlier study. As mentioned in the literature, one of the mediators of the constraint-creativity relationship that specifically relates to constraint source is intrinsic motivation. Unfortunately, we did not gather data on intrinsic motivation in our original study, thus making it hard to draw conclusions on how it mediates the effects seen here. In future studies specifically designed to examine the relationship between constraint source and creativity we would be sure to test for the effects of intrinsic motivation on this relationship.

Other limitations in our study relate to the task and participants. Because this study was not conducted on individuals with a design background the scope of the design task and constraints in this study was limited. Going forward we want to examine how this experiment can scale by looking at how designers will fare with more complex design tasks and constraints. This will be an important next step not only because most design tasks are highly complex but also because as Stokes notes, through training and practice people become better at employing self-imposed constraints (2001).

6. Conclusion

As we have noted, prior research conducted on constraints and creativity demonstrates the complexity of the relationship between the two. While the study discussed here will not provide the answer to all our remaining questions on the topic, it takes a previously under-explored variable and provides one possible explanation for discrepancies in the research. It also provides us with an additional tool for maximizing creativity in the face of constraints.

Our experiment demonstrates that solutions utilizing the same constraint, of the same severity, can exhibit both limited and increased creativity. This is consistent with the mixed findings seen in the existing research. These results imply that the relationship between constraints and creativity is not direct and can be influenced by other factors. Unfortunately, the existing research focuses more on the constraints themselves than on the impact, direct or indirect, of contributing factors. Our study demonstrates the influence of constraint source on the constraint-creativity relationship, such that self-imposed constraints have a positive effect on novelty whereas external constraints have a negative effect on novelty. Usefulness was not affected by constraint source.

We hope that our work will be able to make both theoretical and practical contributions by providing further insight into the constraints-creativity relationship and by providing suggestions for how to better approach projects in need of creative solutions.

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