TIME CONSTRAINTS IN DESIGN IDEA GENERATION

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ABSTRACT
It is generally believed that time pressure can hamper creative work. For design researchers, this belief is only one of the many time related claims that are short of any solid scientific basis. During previous years, design research has witnessed the birth of a new offspring, *design idea generation* research. This has lead to a range of systematic, psychologically-motivated studies that have identified principles behind a successful, efficient idea generation process. With this regard, it is surprising the effects of time constraints have not been thoroughly investigated so far. In this review paper we seek to clarify the temporal dimension in design idea generation by examining parallel time studies on various creative tasks. We start by analyzing the time constraints of design idea generation. We introduce three categories for time related effects: *duration of a task, time decomposition of a task,* and *time pressure*. For each category we review studies regarding its effect on idea generation. The main discoveries are that time decomposition can increase the productivity of idea generation, and while time pressure usually increases productivity, creativity can be compromised by both scarcity and abundance of time. We conclude by arguing that the controlled application of these time constraints can increase productivity and creativity within design idea generation.

Keywords: Idea generation, creativity, design cognition, time pressure, conceptual design

1 INTRODUCTION
All design projects include sessions intended to produce solutions for new design challenges. Often they are referred to as brainstorms. Sometimes the participants of these creative meetings feel they are engaged in a pointless activity. In other circumstances, they may feel devastated by inadequate time to meet a creative challenge, being certain that they will fail. If these scenarios sound familiar, you have probably experienced poor management of time.

All design meetings have a beginning and an end, but what happens in-between varies remarkably from one meeting to another. The documented history of successful idea generation practices [e.g. 1, 2] spans already over fifty years. One idea unanimously promoted by this literature is the presence of a facilitator (or moderator) in idea generation sessions. The facilitator is expected to be the referee of the creative game, ensuring that the rules of the game are adhered to. But the book about the golden rules of idea generation (IG) is not a very comprehensive one yet. One of the unsettled issues concerns the temporal organization of IG. How much time does idea generation require? How should the given time be spent? For how many consultancy hours are you willing to pay for to get new product ideas?

In this paper we attempt to answer these questions through a literature review. We investigate the existing studies of time dynamics from different IG studies located using the ISI Web of Knowledge (Thomson Reuters) and Google Scholar databases in early 2009. Both individual and group level studies are included. Our goal is to present the most relevant findings, demonstrate the limitations of present research, and establish recommendations for practice grounded in scientific evidence. To focus our work, we have excluded the time related issues of group cohesion, member familiarity, role adoption, etc., even though they are real phenomena among groups that work together over longer periods of time [see 3]. However, we expect that after reviewing the evidence, the reader will agree that the traditional ways of managing (or ignoring) the temporal dimension are indisputably outdated and there is also definite need to carry out additional research about the topic..

1.1 Dimensions of Time in Design

In order to understand the time constraints' importance to design creativity, we must begin by opening up the process of design and the sources of the time constraints. Figure 1 illustrates an example formulation of a generic design process. In the design process, the stage of *concept development* includes the task of *concept generation,* which can be further broken down into several steps of design problem solving. We acknowledge that the nature of product development can differ from project to project. A project can target new product platforms, platform derivates, incremental product improvements, or radically new products [4]. The derivate and incremental improvement projects will most likely have very different time requirements compared to the projects aimed at producing new platforms or fundamentally new products. For example, an incremental development project is likely to be allocated with less resources than the development of completely novel products. The differences in these time resources might be labeled *organizational time constraints*. This means that the creative work must be completed within a certain time frame in order to provide sufficient input for the following stages of product development. This also dictates that all measures of innovation management in a design organization have an impact on "the creative department" as well [cf. 5]. But what is this department and how does it fit to the design process. In the generic design process model of Ulrich and Eppinger [4], the most creative step in concept development is concept generation which is a set of sessions needed to produce the idea candidates for systematic exploration. This process is a job carried out under *task-specific time constraints*. The two types of constraints and their relation to the generic development is illustrated below:

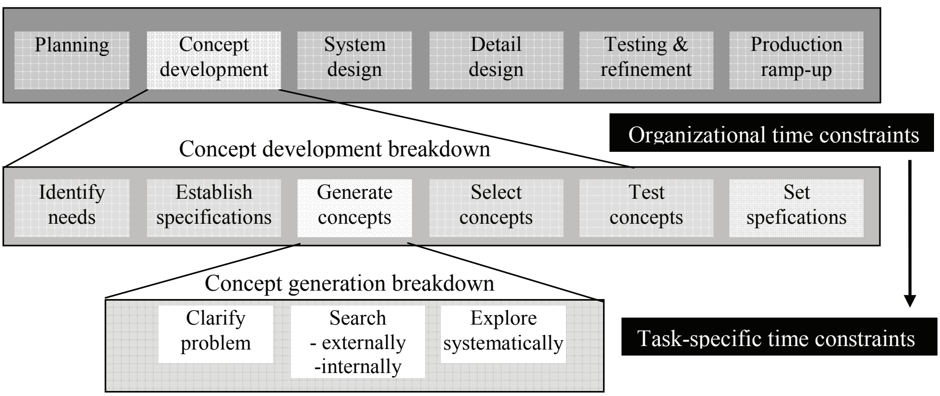

Figure 1. Different types of time constraints relevant to the design process, presented in the context of the generic design process model of Ulrich and Eppinger [4] (an adaptation).

The task-specific time constraints present in a design IG session are the subject of this review. The activities of a design IG session are production, presentation, and decision making. In this paper we particularly elaborate about idea production. We argue that these task-specific time constraints relevant for idea production can be further analyzed into a set of three time-related dimensions:

1. *What is the* ***total time*** *allotted for the session*?
2. *How is time* ***decomposed*** *for the session*?
3. *How does the perceived* ***time pressure*** *affect the creative outcomes*?

Our analysis starts from the necessity to have an overall time limit for session, say one hour (1). Next, the available time can be decomposed into several shorter segments (2), such as e.g. briefing and documentation. The information about the time available and the perception of the difficulty of the given tasks creates the feeling of time pressure, a psychological construct (3). This is the most detailed level of design considered here. Finally, there is time after and between idea generation sessions, which may also be important from some perspectives of creativity (e.g. the incubation effect [6]), but will not be discussed here. We also consider the factors independently, even though that may not fully justified. We believe that the management of these time factors in design practice requires rationale based in scientific studies. Through the relevant research literature we review each factor and finally present some psychological theories that can help us to understand why these effects occur.

For those unfamiliar with design idea generation research, let us briefly describe the common design research methods in order to help understanding the presented results. Design idea generation studies (see, for instance [6-9]) are typically experimental psychological (social or cognitive) studies. They compare groups of people working under different conditions to complete a design task with the goal of producing creative design. By changing the conditions minimally and assessing this effect on the different measures of output, the effect of a certain condition can be evaluated. The most common dependent variable is the number of ideas (sketches, etc.) produced, often referred to as *quantity* or *productivity*. Typically only unique, non-repetitive ideas are considered. Particularly studies that compare real groups with nominal groups (same number of people working independently) employ this procedure to make the groups comparable. Productivity is usually complemented with some other measure of the creativity of individual ideas. Creativity as such is difficult to define [10] and measure, and often researchers settle for either the *novelty* or the *quality* of an idea. Novelty, (also *diversity* or *commonality*), is an index of how common an idea is. Quality can be addressed as *functionality*, *feasibility*, or even *usability*, often with regards to requirements given for the task.

2 TOTAL TIME ALLOCATED FOR IDEA GENERATION

In the generic model of the design process (Fig. 1), the organizational level is expected to provide a time quota for concept development activities. The time for conceptual design is divided between three activities. One of them is internal search which refers to all idea generation activities. This chunk is further split into a series of designer meetings, or brainstorms, during which the actual work is carried out. Our interest is in the time dedicated for a single meeting. How long should the meetings optimally be? If productivity decreases over time, then its trajectory should help us select an optimal upper time limit for design IG, if we wish to ground our processes in rational thinking.

The answer appears so self-evident that no one has apparently taken the question seriously. Possibly under the belief that fatigue surely kills creativity, research on idea generation has been commonly carried out in periods of 20-60 min. There are only a few studies which have studied the function of productivity over time, or manipulated the session length [11, 12]. Howard-Jones and Murray investigated five periods of six minutes, Perttula and Liikkanen three periods of fifteen minutes. These studies showed that in the time frame of 0-40 min there is usually a rapid decline in the rate of produced ideas after the first five minutes. There are other similar findings. A study by Kelly et al. [13] compared individuals working in 10 and 20 min periods in an unusual-uses task context. They found a time function which was quite linear, but showed a minor decrease in the productivity rate after the first 4 or 5 minutes. Very similar results were also retrieved in a study by Snyder et alia [14].

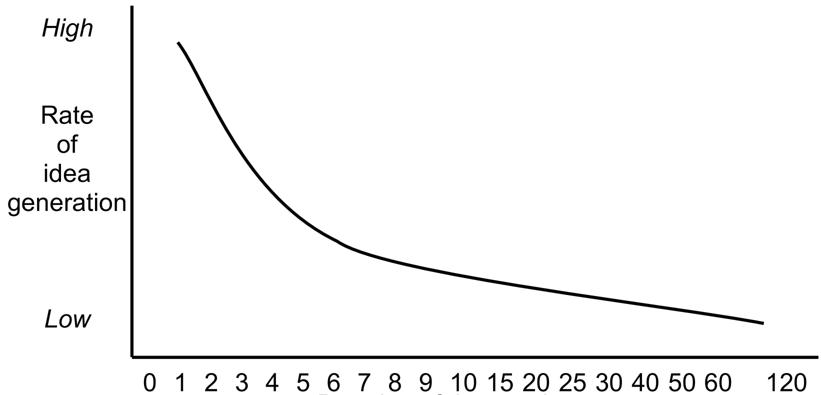

Figure 2. Decline of the idea production rate as a function of session length, interpolated and adapted from [11-14].

What causes this burst of innovation? The initial boost in idea generation may be explained by cognitive theories of memory search [9, 15, 16]. Generating new ideas starts by recalling familiar information from memory. This means that several complete solutions and well-known ingredients can be retrieved and ideas generated relatively fast. However, this will not persist for before long the memory search becomes more taxing. Thus the initial period of high idea generation productivity will likely show negatively in the novelty of the produced ideas.

The conclusion from the referenced studies [17-19], and those to be presented in next section, is that the rate of idea production decreases steadily towards the asymptote out, but does not seem to completely die, as illustrated in Figure 2 on the previous page.

3 TIME DECOMPOSITION

Once a two hour time slot has been allocated for a design IG session, one must decide how it will be used. The idea of time decomposition refers to the division of a longer session into smaller segments, for instance, 20 min for ideation and 20 min for idea selection. Here we will consider two examples of how this comes about in research, through *group working mode* and *time decomposition*.

One recently investigated topic concerns the *group working mode* in idea generation, particularly different group-to-individual –idea exchange procedures [17, 18]. In these procedures, the individuals alternate between working alone and working as a group. This consequently also creates a time split. Paruah and Paulus [17] investigated transitions from *group-to-alone* and from *alone-to-group* during an IG session. Groups of three or four people brainstormed two times for 20 minutes. They demonstrated a significant effect of the working mode, *alone-to-group* being superior to *group-to-alone* [17]. The two time intervals (first and last 20 min) were also unequal. By recalculating the data provided by in the publication, we found that the productivity had significantly decreased from the first session to the second, but the originality of ideas was unaffected. In the study by Perttula et al. [18] a similar procedure involving an *alone-to-group* transition was examined. The study compared regular brainstorming groups of 2 or 4 persons, a nominal non-interactive group, and 2 or 4-person groups going through *alone-to-group-to-alone*–cycle. It was found that the greatest quantity and variety was achieved in the group of four people using the cyclic idea exchange method.

Time decomposition can also occur in association to *task decomposition* [19]. In this case, the time decomposition follows from the break down of a creative task into smaller sub-tasks. Dennis et al. [19] contrasted 10 and 30 minute group idea generation task so that participants completed a full task in 30 minutes, a decomposed task in 30 minutes, the decomposed task in 3 x 10 minute or the full task in 3 x 10 minutes. They found that although the task decomposition affected the productivity significantly, the time decomposition itself neither affected productivity or quality, nor interacted with task decomposition.

In summary, to our best knowledge there is no evidence to suggest that time decomposition in itself would be a helpful strategy (nevertheless, see the next section). However, when used in conjunction with task decomposition or working mode, it can be beneficial. For example, alternating between working individually and in a group can lead to improved results in terms of both quantity and quality.

4 TIME PRESSURE

Our analysis of time pressure starts again from the *organizational time* constraints. These have been studied by Amabile and her associates who investigated time as a resource and pressure factor in creative organizations [20, 21]. From real organizations, they have by observation, interview, and questionnaire studies gathered evidence that the relation of time to productivity follows a U-shape, curvilinear function. This means that both having too little and too much time can be detrimental. This finding about organizational time constraints has also been replicated by Baer and Oldham [22] in an industrial setting while investigating how different organizational factors influence creativity. The curvilinear relationship is illustrated in Figure 3 on the next page:

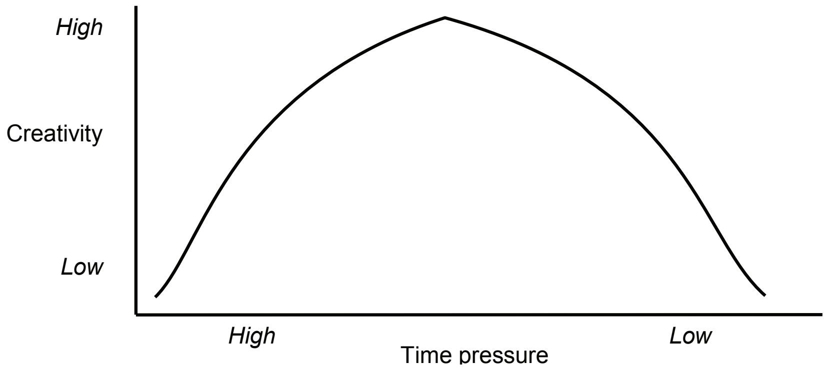

Figure 3. Curvilinear relationship of time and quality (creativity), based on [22] and [20].

It should be acknowledged that time pressure is a psychological construct that people commonly perceive when they have too little time for a duty. Therefore time pressure is a subjective measure and emerges as a product of task demands, allocated time, and own competence. On the task-specific time constraints level, there are few studies that investigate directly how time pressure affects creative work and IG. The effect of time pressure has been studied in relation to several tasks, for instance, many studies concern decision making under pressure (such as [23]). In a review by Kelly and Karau regarding non-creative tasks performed under pressure [24], it is stated that a "fairly consistent finding is that rate of performance, or group productivity, increases under conditions of time pressure." On the other hand, they claim that time has a positive linear relationship to the indicators of solution quality. We will next consider in detail the existing evidence relevant for design IG.

Time pressure in idea generation has been studied by comparing several time limits to complete a task and evaluating the differences in output. Kelly and Karau [24] studied three person groups completing an unusual-uses task for 4, 8, or 12 min. Beforehand they had evaluated that the optimal time for the task was 10 min. They observed that the 4 minute groups generated solutions at a significantly higher rate than 8 or 12 min groups (4.6 ideas/min against 3.1 ideas/min). However, the average creativity of the ideas was somewhat lower in the condition of the greatest time pressure than in the other conditions. There were no significant differences between the 12 and 8 min conditions.

Karau and Kelly also ran another experiment involving small group creativity [25]. Studying 36 groups of three students each, they provided the groups with scarce, optimal, or abundant time (10, 20, or 30 min. respectively) to complete a creative planning task. Again they found that the scarcity of time increased productivity considerably, but decreased creativity and originality somewhat. The only benefits of abundant time were increased presentation quality and task pertinence. These results are consistent with their attentional focus model that predicts that under time pressure efforts are more concentrated towards completing the task, whereas non-task related activities increase when more time is available (see Figure 4 for a recap).

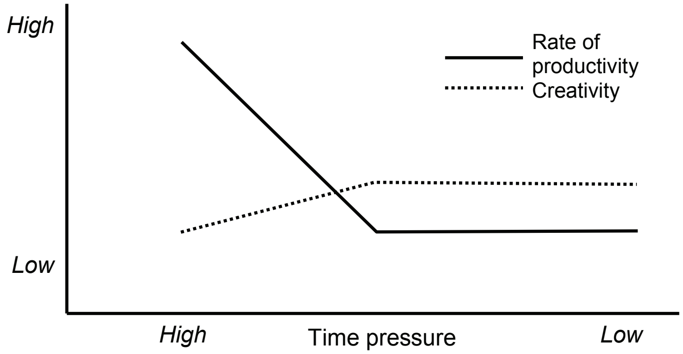

Figure 4. Relationship of time pressure to productivity, and creativity, based on [24, 25].

Another interesting finding from Kelly and Karau's study [24] concerns the dynamics of the time pressure effect. Kelly and Karau presented three creative tasks for groups with either *4-8-12*, *8-8-8*, or *12-8-4* minutes of time combinations. They found that the initial high rates of productivity carried out to the next two tasks and the 4-8-12 group was the most productive of all over the tasks. Interestingly, the observed initial decrease in creativity for the 4 minute group did not persist in the later tasks. This promises that design session could be boosted with a quick, high pressure kick-start task. The authors suggest that these results support the cognitive entrainment hypothesis, which predicts that once a certain rate and style of working is adapted during a single session, this will carry over to the rest of the session even if circumstances should change [13, 24]. The idea of entrainment originates from physiology and biology which have demonstrated the existence of many natural rhythms in human beings. It thus feels natural that work and creative efforts should demonstrate similar nature.

Other studies that support this view also exist. Recently Bechthold and associates [26] have investigated time pressure using 5 and 15 minute intervals and three person groups. They measured several dependent variables and found that the 5 minute condition induced greater productivity, but decreased originality of generated idea. Another study related to creativity under pressure was carried out by Marsh et al. [27]. They studied unconscious plagiarism during an idea generation task, and found that subjects who had very short times to produce answers (20 s.) unconsciously plagiarized more ideas from members of their group in comparison to participants without such time pressure.

Together these studies imply that under pressure, people can surprisingly increase the rate of idea production (at least in the short one-shot team trials commonly used), but at the expense of decreased creativity or originality. This means that creative work seems to adapt to time pressure similarly as other types of activities.

5 DISCUSSION AND IMPLICATIONS

Time issues are of utmost importance to product design. In innovation management, the return on investment is typically calculated in time units, the designers can be paid by an hourly rate and showcasing a new product involves a tight schedule and multiple deadlines. As a result, the temporal constraints embedded in a design project have indisputable but distinct effects on both the quantity and quality of the process outcomes. In this review paper we have attempted to find relevant studies on the effect of time in order evaluate and generate practices of concept design and idea generation. We have presented a review of the literature relevant for understanding how different time constraints influence design idea generation. The different dimensions of time have been explicated and the essential empirical findings have been evaluated. It is evident that time constraints are only one of many factors influencing the creative output of a design team. Time constraints can interact with, for instance, the structure of the task [28], quantitative requirements [13], and examples given to stimulate idea generation [29]. This indicates that there is a clear need to continue this line of research and to put the presented hypotheses to test in design idea generation environments.

5.1 Key findings about each time factor

After reviewing the present research, we now have some material to present as a basis for successful design idea generation practices. For total time allocation we saw that in short intervals, there are only marginal decreases in productivity over time. Based on the presented evidence, the decrease of productivity is unlikely an issue in short sessions (below one hour). Because none of the studies have really pushed the time spans to the extreme, the null hypothesis of ideation fatigue remains untested and this must be considered quite preliminary result. However, if individual and group working modes are mixed, as can happen with task structure decomposition [17, 18] then the saturation point (when the function becomes linear) might be reached more quickly. Nevertheless this is still only a hypothesis for future studies.

Time decomposition alone was not found important, but task structuring and decomposition were helpful in idea generation. Finally, time pressure seems to create quite consistent effects that hold across different task domains, including creative ones. Therefore it seems plausible to argue that design idea generation under time pressure is likely to be productive, but not very creative. If a bit more time would be given, it might decrease the productivity per unit time, but it might also provide a tipping point for unleashing creativity. The studies related to cognitive entrainment theory on the other hand offer an interesting bonus: you may get both high productivity and high creativity if you start with little and then give extra time for the next round.

From all the studies presented here, there are certain trends that can inform design practice. We propose a list which includes the following recommendations grounded on the research reviewed here:

1. *Appoint a facilitator to organize the idea generation meeting* [1, 2]
2. *Define a specific duration for the meeting* [2]
3. *Consider strategies of task structuring and decomposition* [17-19]
4. *Gather experiences to estimate the optimal times for different kind of tasks*
5. *Start the session with a simple warm-up task with high time pressure* [13, 24, 25]
6. *Plan for an optimally short session to tackle the main problem* [13, 20, 22, 24, 25]

5.2 Words of caution – effects of long-term time pressure

There are certain shortcomings that may arise if the present results are interpreted carelessly. One should be aware that the only certain amount of pressure is really beneficial. For example Baer and Oldham [22] only found a curvilinear-like relationship when there was high support for creativity and subjects had high openness to experience, otherwise creativity decreased as time pressure increased. Furthermore, the long-term effect of sustained time pressure on creativity has received little or no research attention. Likely the effects of time pressure are similar to stress: although small amounts of stress can have beneficial effects, when the level of stress is sustained, the effects turn negative (e.g. [30]). In addition to creating health problems, such as cardio-vascular diseases, cognitive functioning is affected [31]. These notions call for further investigations and question whether the benefits gained from sustaining time pressure outweigh their potential cost.

5.3 Limitations of present work

We have attempted to present a review of empirical studies relevant for understanding time constraints in design idea generation. However, this review represents our best knowledge and may not exhaust all possible studies in the area of time in creative group work. However, a more significant concern is that putting together different studies related to group "creativity", we run into many known problems in evaluating creativity. The definitions of productivity and quality, for instance, are quite commonly used, but we acknowledge that there can be certain limitations to how well different studies that seemingly measure the same dependent variables are in fact consistent in their considerations. Also, the results from individual idea generators vs. small groups could sometimes differ. For instance, on a group level, fatigue may not be an issue even in a long idea generation session because turn taking allows a part of the group to enjoy "free-riding" while others speak and work. There are also time-related issues in group interaction we left out of the review. For example, different team roles and dynamics that build up when a certain team works together repeatedly may also have an influence, even if they would not otherwise interact with the variables of the review. The research we have presented has been tested primarily on "one-shot" teams, but we consider them to be valid cornerstones of long-term team work as well [3] and that the present work paves the way for further empirical work on time constraints in design idea generation.

5.4 Future work

Our review has gathered evidence about IG from multiple disciplines but not much was found from engineering design related publications. This indicates that there are plenty of opportunities for conducting research on time factors in design. The studies might include ethnographic observation of real product design teams and their in-depth interviews (cf. [20]) but also experimental studies on different factors, including cognitive entrainment in a conceptual design context. For instance, the curvilinear relationship of time and creative should be verified or design IG tasks as well. We believe that a more thorough understanding of time effects will help in developing research-grounded practices, IG methods, and ultimately innovative and ground-breaking products.

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