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Balancing Constraints and the Sweet Spot as Coming Topics for Creativity Research

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Comments and feedback on the text are highly appreciated.

Abstract

The aim of this chapter is the introduction of two new concepts, '*balancing constraints*' and '*the sweet spot of creativity*', as promising new paths for creativity research. This is motivated by the fact that creativity research shows a growing interest in the fundamental entwinement of constraints and creativity, with skillful and innovative handling of constraints seen as a prerequisite for apt creative performance. Based on a brief review of current disparate conceptualizations of constraints as both enablers and restrainers of creative activities, we begin by proposing the unifying concept '*creativity constraints*' to help establish common terminological ground. Since the presence of constraints change over time, we suggest the term '*constrainedness*' to articulate this total constraint intensity at a given time. This allows us to introduce our main contribution, the concept 'the sweet spot', to address the salient situations where the creative practitioner can be said to experience the 'right' level of constrainedness conducive to optimum creative performance. We then proceed to consider how the sweet spot can be attained by balancing constraints, i.e., by manipulating the intensity of constrainedness. More concretely, this means by hardening or softening the constraints at hand, resulting in a higher or lower level of constrainedness. Finally, we discuss how future studies can employ and inform these new concepts, which we see as potentially rich for cross-disciplinary creativity research focusing on the essential entwinement of constraints and creativity.

1. Introduction

We will begin by considering a mundane example. Imagine that you are working on a creative task such as writing a poem for a loved one on Valentine's Day, February 14. Now visualize two scenarios with highly diverse constraints:

- (1) You have a week to prepare the poem. You have no high ambitions of writing poetry, nor does your partner have any such expectations for the day.

- (2) It is Valentine's Day. You are on the subway and you will meet your partner in 30 minutes. You have no paper to draft on, but you know your partner would appreciate a haiku poem.

Consider the two scenarios and ask yourself the following questions:

How would you approach each of the situations?

In which of the scenarios would you feel that you have the best conditions for being creative?

Which of the scenarios is more likely to lead to the more original poem?

Then reflect: Will more or fewer constraints yield a positive effect on creative performance? The intriguing, underlying question we wish to raise by the above example concerns specific ways to evoke and manage constraints in order to help optimize the perceived potential for creative performance – and thus the originality of the contribution itself.

At any point in a creative process, whether it be decorating cupcakes or building a cathedral, a number of constraints will exist. These constraints mean limitations or restrictions for what can or cannot be done and for what the end result, in the design literature dubbed 'the final design', should fulfill (Gross, 1986; Hull, Jackson & Dick, 2011). Notions of constraints, restraints, and requirements reoccur in creativity research (e.g., Guilford, 1950; Mednick, 1962; Sternberg & Kaufman, 2010), but except from a few recent contributions (Joyce, 2009; Liikkanen, Björklund, Hämäläinen & Koskinen, 2009), little effort has been devoted solely to this relationship. The existing work mainly focuses on the effect of specific types of constraints (e.g., Karau & Kelly, 1992; Amabile, 1998; Baer & Oldham, 2006), theoretical considerations (e.g., Johnson-Laird, 1988; Stokes & Fisher, 2005; Sternberg & Kaufman, 2010), and specific approaches to handling constraints (e.g., Darke, 1979; Richard, Poitrenaud & Tijus, 1993; Maiden, Gizikis & Robertson, 2005). However, as mentioned, recent contributions point to the need for further work on the relationship between creativity and constraints (e.g., Joyce 2009; Liikkanen et al., 2009). Moreover, the concluding chapter of the recent seminal *Cambridge Handbook of Creativity* (Kaufman & Sternberg, 2010) focuses on constraints and the potential herein for informing future theory, which exemplifies the current, growing interest in the entwinement of constraints and creativity.

Existing theoretical and empirical work investigating the relationship between creativity and constraints articulates the complex nature of constraints as both enabling and restraining in creative processes (Negus & Pickering, 2004; Stokes, 2008; Joyce, 2009b; Onarheim & Wiltschnig, 2010). This duality might appear counterintuitive (Anthony, Johnson & Sinfield, 2008) as one could suspect that more rather than fewer creative options at hand would consistently yield the better outset for a process. This strong assumption could also be a reason why most creativity literature seems to focus on freedom rather than on constraints (Joyce, 2009b). Still, (Joyce, 2009b) lists researchers who have pointed out that too vaguely defined problems can in fact lead to confusion, and other authors state that applying constraints can help focus creative effort (Reitman, 1964; Isaak & Just, 1995; Ward, Smith & Finke, 1999; Anthony et al., 2008), and lead to creative breakthroughs (Stokes, 2006). In addition to this dual nature, constraints are also related to both generative and evaluative aspects of creativity (Ball, Onarheim & Christensen, 2010). As such, the notion of constraints appeals to several disciplines related to or within creativity research, e.g., philosophy of sports (Lewandowski, 2007), literary history (Andrews, 2003), management theory (Goldratt, 1990), software engineering (Nuseibeh & Easterbrook, 2000), and, not least, various design domains (e.g., Gross, 1986; Darlington, 2002; Lawson, 2006). However, what soon becomes apparent is the lack of consensual terminology and shared scientific scope in the reviewed literature. The present chapter does not only recognize constraints as lying at the core of

creativity, but further argues that creativity cannot be conceptualized, studied or understood without considering the complex nature of constraints.

To be able to explore the intimate relationship between creativity and constraints more fully, thereby paving the way for our main contribution, the first step in what follows is an attempt to establish a transparent conceptual framing of constraints overarching the disparate terms presented by current studies. Our proposal, the concept '*creativity constraints*', as well '*constrainedness*' to articulate the total intensity of constraints present in the process at a given time, comprises the main part of section 2. In section 3 we introduce the concept of an individual '*sweet spot*' to address the particular situations where the level of constrainedness seems just 'right' with regard to creative performance, i.e., neither too many, nor too few constraints for the creative practitioner to perform efficiently and satisfactorily. The manipulation of constraints to vary the level of constrainedness is what we mean by the notion '*balancing constraints*'. Given that we see our conceptual contribution as a small step toward a more comprehensive investigation of the entwinement of creativity and constraints, section 4 accordingly addresses immediate paths for future studies within cross-disciplinary creativity research focusing on the various ways in which different kinds of constraints affect creative performance. We end the chapter by a few concluding remarks in section 5.

2. Toward A Unifying Framing of Creativity-Related Constraints

As will be outlined below, one of the key challenges for current research into the relationship between constraints and creativity is that the focus on constraints is either wide-open in a nearly all-embracing, abstract manner or more myopic in scrutinizing the impact of highly specific constraints (see also Biskjaer, Onarheim & Wiltschnig, 2011). In addition to the important recent contribution by (Kaufman & Sternberg, 2010), our previous work (Onarheim, 2012; Biskjaer, 2012) provides a thorough review of past and present work on the relationship between constraints and creativity. Following arguments by (Mamykina, Candy & Edmonds, 2002), we subscribe to the idea of the need for a shared terminology as a prerequisite for cross-disciplinary advancements. Thus, an obvious first step involves the formulation of clearly defined key concepts. In order to take steps toward a more transparent terminology, we will briefly outline some of the main conceptualizations of constraints.

2.1. Current Conceptualizations of Constraints

Work on constraints so far can be divided into two clusters, a) *generic typologies* aiming to provide an all-embracing conceptualization of constraints, and b) *ad hoc-typologies* working with specific constraints such as time frames, budgets, materials, etc. As discussed in more detail in (Biskjaer & Halskov, in press; Onarheim, 2012), generic typologies of constraints (ad a)) comprise three main contributions, among them Lawson's cubic model (Lawson, 2006) consisting of thirty-two boxes representing configurations of design problems. More art-oriented are Stokes various conceptualizations emphasizing how careful management of constraints in oppositional pairs (dichotomies) may allegedly yield creative breakthroughs (Stokes, 2006). However, most beneficial for the present purpose is Elster's fundamental (ontic) tripartition of 1) intrinsic (immediately given by or inherent in the context), 2) imposed (by external agents such as stakeholders who have an interest in influencing the process and outcome), and 3) self-imposed constraints (instigated by the creative agent herself). In addition to these three main, generic typologies, there is a significant number of individual contributions to constraint research, each focusing on one particular constraint in a particular context within a particular domain. The aggregate of these studies is what we subsume under the epithet *ad hoc-typologies* (ad b)).

2.1.1. A Meta-Categorization of Current Work on Types of Constraints

Rather than adding yet another discipline-specific sub-typology, cf. our notion of ‘ad hoc typologies’, (Onarheim, 2012) groups together the numerous types described in the current literature, thereby presenting a pattern of resemblance in the total pool of the three main generic typologies and the array of more specific ad hoc-typologies. What is remarkable when looking at this pool of current work on constraints is the lack of shared scope and terminology, as very few studies seem related to, let alone informed by, each other. Also, the breadth of definitional specificity is vast, ranging from Elster’s philosophical musings to pragmatically oriented studies based on an apparent domain-specific, consensual and thus unarticulated understanding of a particular constraint and its impact on a process. A systematizing review of current work on constraints suggests that (at least) seven categories of types of constraints can be discerned (Onarheim, 2012):

- Individual (e.g., skills, habits, mood, motivation, ambition, principles)
- Social (e.g., team, expectations, conventions, chemistry, communication)
- Process (e.g., time, cost, tools, environment, formal procedures)
- Technical (e.g., requirements, regulations, production, material)
- Source (e.g., user needs, subject, client, task)
- Domain (e.g., internal, external, inherent)
- Purpose (e.g., validity, non-functional, quality)

It should be stressed that this meta-categorization of current constraint typologies, generic as well as ad hoc, is not meant to be exhaustive, nor are the distinctions between them absolute. Rather, the systematization above marks an attempt to cluster some of the most important uses and conceptualizations of constraints in the literature that upon closer scrutiny soon appear to be too numerous to mention in full.

2.1.2. Toward a Synthesizing Conceptualization of Constraints

While the list above offers a way to demarcate types of constraints in current literature in the form of seven primary categories, we wish to argue for an alternative way to address and articulate constraints and their complex nature and impact on creative processes. Existing typologies, generic as well as ad hoc, tend to rely on a focus on a limited selection of certain traits of the constraints, at times denoted features, characteristics, or dimensions (Onarheim, 2012). Often, only one such dimension is investigated in the study, which conveys a static model displaying a snapshot-like view of constraints at a given stage in a creative process. An alternative to this view is seeing constraints as operating within a multidimensional space of continua (Onarheim & Wiltschnig, 2010). More concretely, this means that we consider each constraint as having *multiple dimensions* that can be investigated, and further that each constraint is embedded in and potentially affects several *continua* within each dimension simultaneously (Onarheim, 2012). Following ideas of using continua as a form of conceptualization (Stacey & Eckert, 2010), we wish to argue that a more pragmatically oriented and more comprehensive, but non-exhaustive, understanding of constraints would be one bridging current typologies, thereby emphasizing the many different constraints’ shared characteristics, or as we prefer to call them, dimensions, as they emerge in and affect the creative process. While the meta-categorization above marks an attempt to demarcate (some of) the numerous types of constraints featured in current work, Table 1 below (Onarheim, 2012) aims to present a synthesizing conceptualization of creativity-related constraints regardless of their adherence to a generic or an ad hoc-typology. Thus, the table offers a concrete means to articulate similarities, hereafter called dimensions, between constraints as a tentative step toward a more coherent understanding of creativity-related constraints.

Dimension	Description	Continua
Articulation (or formalization)	The extent to which the constraint is articulated	Formal vs. tacit Explicit vs. implicit Written vs. verbal
Abstraction (or hardness)	The level of details in the description of the constraint, also related to possibilities for measurement	Soft/fuzzy vs. hard Ill- vs. well-defined Abstract vs. concrete
Complexity	The level of difficulty in adding the constraint to existing solutions	Complex vs. simple
Flexibility	The extent to which the constraint is fixed in its current form	Non-negotiable vs. negotiable Fixed vs. flexible
Importance	The important of taking the constraint into account	Nice-to-have vs. must-have Desire vs. demand
Origin	From within the agent or externally imposed	Internal vs. external
Timing	The point in a process where the constraint appears	Initial vs. late

Table 1: Dimensions and Continua for a Synthesized Conceptualization of Creativity-Related Constraints.

It should be noted that these seven dimensions are theoretical constructs that exemplify a part of the larger number of terms employed in current work (see also Reitman, 1964; Jul, 2004), so this alternative conceptualization is not intended as a replacement for more specific investigations of constraints at a sub or even micro-level. As will become apparent, using continua to present key dimensions of constraints entails an important advantage, which concerns the malleability of constraints as a way to affect the creative process itself. However, to do so, a very first step means establishing an overall conceptual framework for the somewhat vague notion of ‘creativity-related’ constraints.

2.2. Introducing ‘Creativity Constraints’

Derived from the Latin verb ‘constringere’ meaning to restrain, compress or bind together (NN, 2003), the noun ‘constraint’ is in itself problematic, not only semantically, but also due to the broad and often scarcely defined conceptual use of the concept in creativity and other strands of research. For the sake of further studies of the relationship between creativity and constraints, it should be discussed whether the term itself is too vague to be useful as a unifying descriptor for the various existing types of limitations on creativity. To offer a clearer distinction between other uses of the word ‘constraint’, thereby avoiding future confusion as well as unifying future research efforts, we suggest using a specific descriptor for constraints when seen in relation to creativity. Since other researchers within creativity studies apply the term ‘constraints’ to describe more concrete elements in design processes, e.g., cognitive constraints (Amabile, 1996) and subject constraints (Stokes, 2006), we see the need for coining one generic term to embrace the heterogeneous usage of the term ‘constraints’. Our suggestion is the overall term ‘*creativity constraints*’ as a basic means to address the entirety of constraints that might affect creative agency, spanning from technical and practical to social and cognitive constraints. Accordingly, a tentative definition of creativity constraints is as follows:

Creativity constraints are explicit or tacit factors governing what the creative actor/s must, should, can and cannot do; and what the creative output must, should, can and cannot be.

This, however, does not entail abolishing the need for more specific sub-typologies of constraints. Rather, our suggestion of the term ‘creativity constraints’ is meant as a synthesizing concept to help offer a framework to tie together a number of strands of research each sprawling with their own (sub-)types of constraints in the context of creativity. As a next step, more specific elements of constraints should be considered in further studies, more concretely an elucidation of the dimensions as illustrated above, among other topics..

2.3. Introducing ‘Set of Constraints’ and ‘Constrainedness’

In our previous work (Onarheim, 2012), the notion of ‘*set of constraints*’ (see also Johnson-Laird, 1988; Ajit, Sleeman, Fowler & Knott, 2008) is utilized as an expression of the sum of constraints at any point in time during a creative process. In our comparison of creativity constraints in engineering design and filmmaking (Biskjaer et al., 2011), we employ another term that we deem important in studies of creativity constraints: ‘*constrainedness*’ (Glück, Ernst & Unger, 2002). This concept articulates the total level (intensity) of the experienced constraints at a given point in a creative process. Conversely, it states the perceived degree of freedom. Informed by the distinction between over-constrained vs. under-constrained problems in (Stacey & Eckert, 2010), although without their cross-domain scope of analysis, our notion of constrainedness expresses a total indication of the intensity of the pertinent set of constraints at a given stage in the creative process. Each constraint affecting a creative process can feature (at least) seven dimensions as exemplified in Table 1 above. For each of these dimensions, the constraint can be analyzed, which reveals its tentative placement on the various continua adhering to the individual dimension. Some constraints will be fixed, some are more flexible; some will be rather abstract, others very concrete; some will be presented from the beginning, while some will only arise late or at the very end of the process. Thus, the higher/lower an individual ‘score’ on each of these continua, the higher/lower the final ‘score’ for each constraint. Each constraint pertinent to the creative process can be articulated in this manner, and the *total ‘sum’* of these creativity constraints expressed on continua indicates the total level of *constrainedness*. Any situation or process presents different levels of constrainedness depending on the number and abstraction of the constraints, as discussed in (Onarheim & Wiltschnig, 2010), and altering just a single constraint leads to a different set of constraints with a different level of constrainedness.

The two concepts ‘set of constraints’ and ‘constrainedness’ do not imply the existence of a complete and graspable entity of ‘all constraints’; nor that all constraints can be captured, understood, or mapped. Thus, since there is no objective measure for all constraints, or for the limiting effect of each constraint, there is no exact or objective measure for levels of constrainedness (hence the inverted commas around ‘sum’ and ‘score’). Rather, the concept is a theoretical (phenomenological) construct to state how free – or restrained – a practitioner experiences a given situation in a creative process at a given time. Additionally, due to the complex nature of constraints, the relationship between number of constraints and level of constrainedness should not be considered fixed. In the introduction above, two different scenarios for writing a poem were introduced, representing two different sets of constraints with two levels of constrainedness. The point we wish to make is that the varying levels of freedom a creative practitioner goes through in a process may be expressed as experiences of constrainedness based on changing sets of constraints. Admittedly, ‘set of constraints’ says little about the various constraints it comprises, let alone their relative importance. To address this issue, we will now briefly consider what we have found to be creativity constraints of special interest.

2.4. Creativity Constraints of Special Interest

Concurring with related findings (among others Joyce, 2009b; Liikkanen et al., 2009), our recent studies (Biskjaer & Halskov, in press; Onarheim, 2012) point to the need of further probing the notion of constraints, since some constraints inarguably appear to bear more impact on both the creative process and outcome than others. Although more studies are needed to investigate which constraints require more attention, we wish to offer a brief overview of some of the constraints that our studies indicate are particularly interesting. As with the above meta-categorization of types and the synthesizing outline of dimensions (cf. Table 1) there are no absolute borders between these constraints, and some may quite possibly be considered overlapping. This overview forms the last part of the basis for the upcoming introduction of the sweet spot and how it can be attained by handling constraints in a skillful and innovative manner.

2.4.1. Crucial Constraints as a Tool of Prioritization

In (Onarheim, 2012) it appeared that the experienced designers needed very little time to identify some specific constraints, and these were initially the main focus of the design teams. The selection of certain constraints as the main focus for the creative effort was also observed in our study of expert filmmakers (Biskjaer et al., 2011), described as an act of ‘pick your battles’. In our study of expert software designers (Ball et al., 2010), an overlap between the constraints categorized as complex by the researchers and the ones initially emphasized by the software designers point in the direction that these designers apply the same strategy as the designers and the filmmakers. This initial focus on crucial constraints resonates well with the observations of some constraints being more challenging or time-consuming than others (e.g., Onarheim, 2012).

2.4.2. Self-Imposed Constraints as a Creative Resource

In an ongoing comparative study of art and engineering design as constraint-reliant domains, the creative professionals we have observed have all added their own constraints to the given set of constraints, seemingly as a way to make it easier to navigate (see also Biskjaer et al., 2011). With regard to the engineering designers, the self-imposed constraints were furthermore observed to be as important as the externally imposed constraints (Onarheim, 2012). Although initial findings strongly suggest that creative practitioners continuously rely on self-imposed throughout a creative process, the question arises as to the relative importance of these self-evoked limitations on action. Each choice made can be said to affect the creative process by changing the constrainedness, however, some choices of constraints seem in fact decisive for the final result. In our current work (Biskjaer & Halskov, in press), which is also inspired by Darke’s (Darke, 1979) work on primary generators and their relation to the end product, we have further explored this salient feature of self-imposed constraints. Looking at media façade installation projects within interaction design, we have suggested to coin the term ‘decisive constraints’ to encompass a particular category of self-imposed constraints that have lead to not simply an incremental progression, but a turning point in the creative process by becoming decisive for the final result. This exemplifies how manipulation of the creative space of action and the level of constrainedness make for a resource that can help attain highly original creative outcomes.

2.4.3. Late Constraints and Their Effect on the Creative Process

In addition to self-imposed constraints, initial (pre-given) constraints are often changed, or constraints are externally added or removed throughout a creative process. Each time a set of constraints is internally or externally changed, it calls for a revision of the existing solution(s). As remarked in (Onarheim, 2012), when such late constraints were introduced, the engineering designers studied made a big effort in adapting the existing solution to these new

constraints in order to avoid discarding previous efforts. This observation is closely related to the ownership bias found in (Onarheim & Christensen, 2012) when studying company-wide voting schemes for idea selection in product development. In the study, the individual evaluators of ideas tended to prioritize their own ideas for furtherance; an effect so potent that for every evaluator there was a higher average proportion of picks for ideas that the voter had worked with than ideas not worked on. In the projects described in (Onarheim, 2012), the process of adapting existing ideas often required painstaking creative work motivated by “*not giving up on a good idea we’ve worked on*” (ibid., p. 346). Thus, it can be assumed that if the constraint was part of the set of constraints from the beginning, some of the solutions successfully adapted would have been discarded as incompatible, and it is actually the addition of late constraints that leads to the investigation of these solutions. This shows how the introduction of a constraint, regardless the source, may initiate new creative processes, emphasizing the importance of ‘late constraints’.

2.4.4. Exigent Constraints as Challenges in the Creative Process

While late introduction of constraints can have a positive effect, several authors have shown how concrete constraints can have a negative influence on creativity (for an overview, see (Onarheim & Wiltschnig, 2010). Constraints that are difficult to manipulate might limit the possibility of balancing the constrainedness, thereby decreasing the potential for the search for the sweet spot. This holds especially true in collaborative settings, which entail substantive negotiation in terms of choices for and against variables in the creative process. In (Onarheim, 2012), constraints without background, explanation and/or a clear owner appeared to be a strong barrier for creativity, as manipulating the constraint was difficult without investing time in examining the constraint. In this way, potentially flexible constraints can accidentally be perceived as highly fixed, when the rationale or owner of the constraint is not clear. Furthermore, tacit constraints such as beliefs held by designers (e.g., “*We know that they [Management] would never agree to (. . .)*”, ibid., p. 331) also appear to be a barrier for creativity, as they can lead to accidental exclusion of potentially valid solutions. Exigent constraints, we found, emphasize the importance of careful attention to the amount of fixedness or flexibility of each constraint and thus the overall intensity of the perceived constrainedness at a given stage of the creative process.

3. Balancing Constraints and The Sweet Spot

To better understand the nature of various constraints and how to manage them in a proficient and fruitful way, we have previously studied individual views on this through interviews and observations. In our cross-domain comparison (Biskjaer et al., 2011), two expert filmmakers explicitly agree that ‘no constraints’ is the most evil challenge they can impose on each other in a filmmaking process. Accordingly, in (Onarheim, 2012), some engineering designers explained how having a lot of constraints rendered it easier for them to be creative, as “*less time is wasted on being lost*”, while others emphasized the importance of creative freedom (ibid., p. 344). Furthermore, specific constraints were conceived as limiting by some, but enabling by others. Even more importantly, it is a key observation with regard to both the filmmakers and the engineering designers that the exact same constraint was described as both limiting *and* enabling by the same person on different occasions. Examples of this were a specific ‘production method’ and an extremely tight shooting rate of only ‘12 frames per second’, respectively (see also Biskjaer, Dalsgaard & Halskov, 2010). Thus, there seems to exist a dynamic and context-dependent individual perception of the limiting effects of constraints. This supports the assumption that it is not necessarily a question of a set of, or single, constraints being *either-or* in terms of their effect on creative agency; rather, the

constraints act as *both-and*, as described in (Onarheim & Wiltschnig, 2010), stressing how the idea of prescribing just the ‘right amount’ of constrainedness once and for all seems little feasible. Rather, handling the constrainedness in a given moment is relative to the situation and persons involved at a given stage in a given creative process. That said, we believe a pattern can be discerned from studying the ways a fruitful space of creative action is transformed, culminating in the so-called *sweet spot*. As will appear, the sweet spot can be reached via skillfully and innovatively balancing the constraints at a given stage in a creative process.

3.1. Balancing Constraints to Encourage and Elevate Creative Performance

As part of our studies of specially interesting constraints as presented in section 2.4., we have also identified and described how creative experts execute concrete strategies for creative constraint handling, namely *blackboxing*, *removal*, *introduction*, and *revision* (Onarheim, 2012; Biskjaer et al., 2011). When *blackboxing*, the actors decide to treat specific constraints as unchangeable to be able to focus on the ones considered more crucial. While in the process of constraint *removal*, highly fixed constraints are temporarily ignored to open up for solutions that might have been overseen. Furthermore, self-imposed constraints can be introduced as a way to get out of situations where the actor is either ‘lost’ or ‘locked’. In the fourth activity, constraint *revision*, the creative actor seeks to solve creative hindrances by going back in the process to review problematic constraints.

These four approaches to proficient handling of constraints as a way to boost creative performance introduce an interesting element within innovative constraint management. These strategies enforce a view of a set of constraints as a dynamic entity to be manipulated, or even played with, in order to achieve a different level of constrainedness, thereby potentially producing a more suitable basis for creative performance. This action of manipulating set of constraints to reach another, higher or lower, level of constrainedness represents an interesting act of balancing the dual nature of constraints aiming to instill a suitable amount of confinement in terms of creative space of action. A very simple metaphor for this would be the task of establishing the proper setting for an informal football match with a group of friends. In such a situation, both the size of the pitch, the number of players, and the rigidity of the rules the players must adhere to must neither be too ill-defined or broad, nor too rigid or small for the game to work, let alone be entertaining. Accordingly, the creative space of action must navigate such extremes.

Based on the assumption that there is no exact measure for levels of constrainedness, it is not feasible to define in absolute terms what is too much or too little amount of constraint pressure, i.e., too low or too high a level of constrainedness, to help optimize creative performance. The notion of ‘too low’ and ‘too high’ is thus considered a subjective and context-dependent measure, and the creative potential for any given situation is as such not objective, and the core element in creative constraint handling is related to the balancing act giving by this double-bound nature of constraints. If both ‘too high’ and ‘too low’ a level of constrainedness can have a negative influence on creativity, this act of manipulating constraints to balance constrainedness is considered a search for what we suggest be called *the sweet spot of creativity*.

3.2. The Sweet Spot of Creativity

Onarheim (Onarheim, 2012) introduces the concept of a subjective and relative ‘sweet spot’ representing the level of constrainedness at any time of the creative process where the participants perceive that the intensity of the present constrainedness is particularly

conducive to creative performance. Also, the study exemplifies how the creative practitioners observed seem to search for such a sweet spot through manipulating and playing with constraints. This finding is in line with the active balancing between openness and rigidity of constraints as proposed by (Onarheim & Wiltschnig, 2010). Interestingly, and perhaps even surprisingly, the creative work observed in the study in (Onarheim, 2012) did not focus solely on reducing constrainedness, and in the beginning of new projects rather than trying to simplify the challenge at hand, the designers in fact sought a way to reduce the variety of potential solutions to the then not fully comprehended challenge by introducing their own constraints. Put simply, the sweet spot marks what in more layman terms could be called the individual's 'creative comfort zone'. We are aware of the link to the notion of a problem-solution space (Dorst & Cross, 2001), however, it is beyond the scope of this introductory chapter to explore this linkage in detail. For the present purpose, suffice it to say that the sweet spot articulates the situation in which creative professionals such as designers feel most comfortable working, i.e., where they feel they are in fact most *creative*.

3.3. Basic Model of Constrainedness and the Sweet Spot

Based on the considerations above, Figure 1 is proposed as a model to help visualize the concept of the sweet spot as being extraordinarily conducive to creative performance.

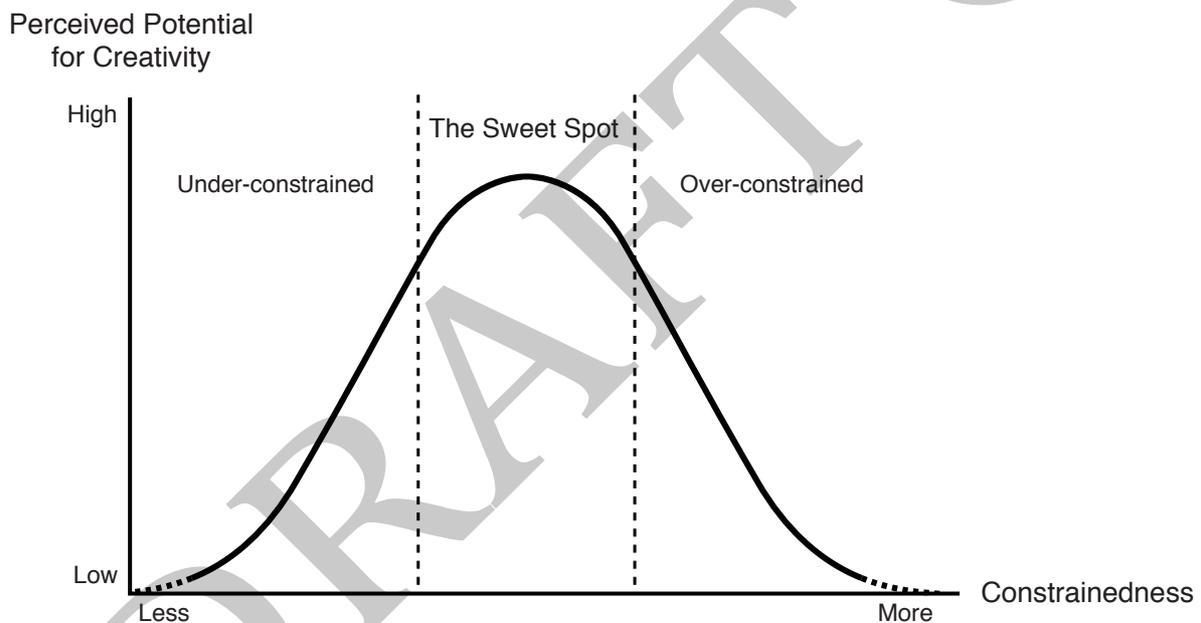


Figure 1: Basic Model of Constrainedness and The Sweet Spot of Creativity.

Figure 1 represents a snapshot of 'any given point' of a creative process as seen from an individual perspective. The horizontal X-axis shows the relative 'constrainedness', i.e., the severity of the set of constraints affecting practitioners at a given point in time in the process, as outlined above. The vertical Y-axis indicates the 'perceived potential for creativity', by which we mean the feeling or experience of creative potential and personal aptitude in the situation. Thus, the inverted U-shape illustrates the perceived potential for creativity as a function of the constrainedness, exemplifying both the sweet spot and the under- and over-constrained areas, respectively, on each side. Moreover, the inverted U-shape conceptualizes how the perceived potential for creativity decreases in both the direction of 'more' and the 'less' constrainedness, following concepts and ideas of employing a continuum to express a varying intensity of constraints, cf. the terms 'over-' vs. 'under-constrained' problems, as proposed by (Stacey & Eckert, 2010). As appears on Figure 1, the inverted U-shape is dotted in each side to the far left and far right, respectively. This is motivated by the concern that

there is no proper origin (where the two axes meet) in which the perceived potential for creativity is zero. Accordingly, the notion of a non-existent level of constrainedness (value at zero) is an abstraction as all creative processes will exhibit some constrainedness, even though this can be conceived of as a limit value (see also Biskjaer & Halskov, in press).

3.4. Constraints and Strategies in Various Domains

Although Figure 1's inverted U-shape expresses a snapshot-like conceptualization of the correlation between constrainedness and the basis for creative performance, this depiction does not say much about where creative problems to be handled in fact occur. Some creative tasks will from the outset be defined very clearly and in great detail as this is standard procedure within the domain. As preeminent example of this is the engineering designers working with medical products in (Onarheim, 2012). In this case, many of the problems surfacing throughout the creative process will tend to border on being over-constrained. Similarly, more art-oriented creative challenges tend to be characterized by very few dominant constraints. A sculptor, to give an example, enjoys a significant degree of freedom in terms of which materials to use, time available, and so forth. This means that art may be conceived as under-constrained, following the idea of a representational continuum in (Stacey & Eckert, 2010). In both cases, the creative task at hand may occasionally (and fortunately) occur directly in the creative practitioner's sweet spot by sheer chance, i.e., without any deliberate intervention. In such (rare) cases, the practitioner immediately feels inspired and ready to tackle the task at hand without further ado. However, most often our studies suggest that the practitioner does not begin the creative process directly within the sweet spot. This holds true for both art and engineering design as highly disparate domains. Therefore, the practitioners must resort to a number of tools to modify the total constrainedness and its impact on the perceived potential for creative performance. In both previous work (Onarheim, 2012; Biskjaer et al., 2011; Biskjaer & Halskov, in press) and ongoing studies, we have employed observations, interviews, and controlled experiments to investigate various ways by which creative professionals modify the constraints they are facing in order to optimize their basis for creative performance. As mentioned above, the engineering designers in (Onarheim, 2012) were observed to resort to (at least) four different strategies to optimize performance, namely blackboxing, removal, abstraction, and introduction of constraints, as well as focus on crucial constraints. Similarly, the above studies have observed how poets, film directors, and designers choose to introduce additional constraints, i.e., self-set constraints, to make the task more manageable and concrete. One of the key findings from these studies is a proposal for a new conceptualization of how the creative practitioners themselves engage in actual modification of the creative space of action to render it more conducive to creative performance. Put briefly, the creative practitioners appear to alter the creative challenge at hand, to amplify the level of constrainedness in a search for the desired foundation for creative performance.

Figure 2 below shows how strategies for creative constraint handling can be added to the basic model (Figure 1). What Figure 2 illustrates is how these strategies serve as means to manipulate the constrainedness in order to approach and hopefully enter into the sweet spot, cf. the above observation that modifying even a single constraint through an awareness of its dimensions can change the entire constrainedness of the creative challenge at hand. In other words, as a slightly more advanced version of Figure 1, Figure 2 below expresses how entering into the sweet spot is essentially a question of *balancing constraints* in the form of selecting (and de-selecting) the strategies that seem to best promote creative performance.

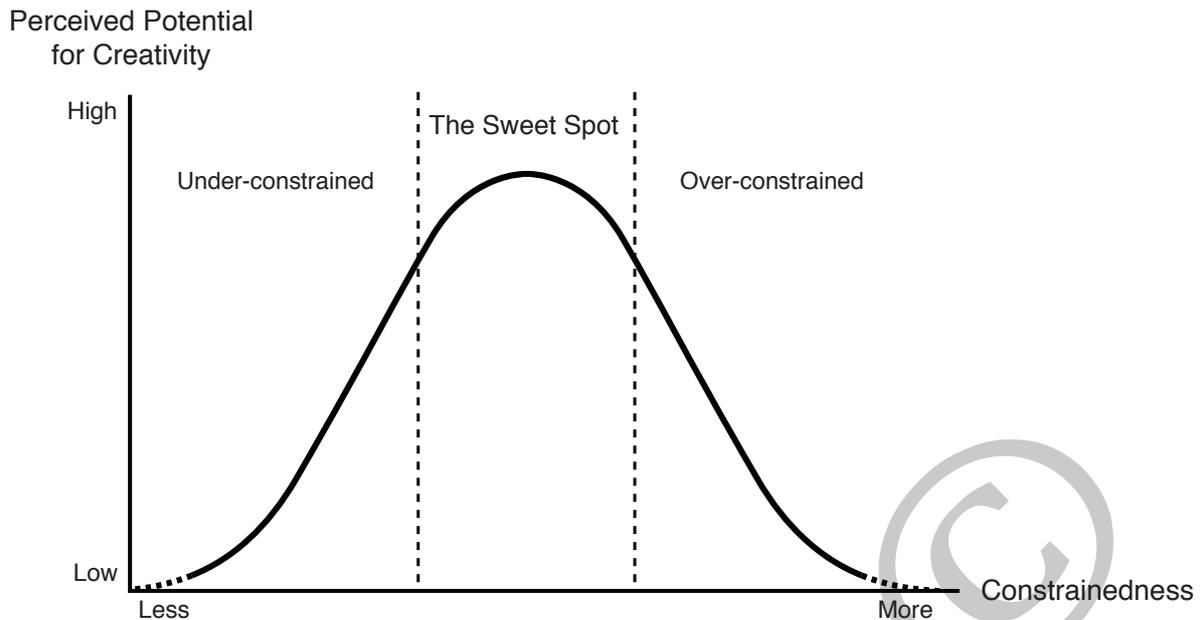


Figure 2: *Advanced Model of Constrainedness and The Sweet Spot of Creativity (with concrete strategies for entering into the sweet spot).*

Figure 1 and 2 are meant as conceptual contributions to help show creativity as a function of constraints in order to illustrate core aspects of the relationship between creativity and constraints in a basic graphical model. The illustrations are by no means intended to give an exhaustive representation of the essential, complex entwinement of creativity and constraints. Rather, the model is proposed as an attempt to provide an initial, conceptual basis for more in-depth discussions of the relationship between constraints and creativity and the search for the sweet spot understood as a highly desirable creative space of action with the ‘right’ amount of creative freedom of action, i.e., where the creative practitioner feel the most at ease, inspired, and productive.

In addition to our own work, the literature reviewed comprises (at least) three studies that seem to point toward the same basic pattern as the one exemplified in Figure 1. Experimental studies performed by (Joyce, 2009b) indicate an inverted U-shaped curve in the relation between creativity and different degrees of constraints, and (Liikkanen et al., 2009) summarize work by (Amabile, 1998) and (Baer & Oldham, 2006) to show a similar pattern for the relationship between creativity and organizational time constraints. The complex of the proposed terms ‘creativity constraints’, ‘balancing constraints’, and ‘the sweet spot’ in combination with the depiction of correlation as featured on the two figures serve to provide greater conceptual transparency as well as offer a small first step toward an improved understanding of creativity constraints and how they affect creative performance. While Figure 1 outlines a basic pattern of correlation, Figure 2 takes this finding a step further by suggesting concrete strategies for entering into the sweet spot. We believe advancing such strategies, not least in a cross-disciplinary perspective, holds a great potential for informing coming creativity research, so in what follows, we will briefly address what we consider obvious next steps in this direction.

4. Emergent Topics in Research into Creativity and Constraints

In our view, the fuzziness of real-world sets of constraints and the nature of conflicting constraints are important to crucial aspects of constraints and constraint handling. We should

stress that we do not hold the belief that constraints are always clear, tidy, and not conflicting; nor that creativity is solely an activity of constraint discovery and satisfaction. Several authors have already pointed to the important creative virtue of breaking the rules and making trade-offs between (seemingly) conflicting constraints (Csikszentmihalyi, 1994; Li, 1997; Chevalier & Ivory, 2003; Stacey 2010). Furthermore, it can be discussed if, in terms of constraints, ‘what is not there’ is as important as ‘what is there’.

4.1. Advancing Tools to Help Balance Constraints

Following the emphasis on the social aspect of creative processes as argued by (Perry-Smith & Shalley, 2003; Warr & O'Neill, 2005), an investigation of the relationship between constraints and creativity on an individual level (cf. our use of ‘practitioner’, ‘agent’, etc. and adhering pronouns in the singular) should be augmented by more studies focusing on collaboration. More concretely, it should be studied whether the concept of optimizing creative performance by moving toward the sweet spot (cf. Figure 2) could also be applied on a team level, assuming that a team can have a shared understanding of both constrainedness and potential for creativity. Further discussions of this representation should also relate to the question of expertise (Cross, 2004; Bonnardel & Marmèche, 2005), as it could be assumed that domain experts are more comfortable in an area of the model that might be considered over-constrained by novices, picturing the inverted U-shape for experts being further to the left of the figure compared to novices. While this argument might indeed be valid for engineers, as their creative skills can be seen as related to navigating over-constrained environments, it might have the opposite effect on poets and kindred artists, if one considers them experts in handling under-constrained creative situations, as proposed by (Stacey & Eckert, 2010). We are currently investigating patterns in the use of self-imposed constraints among poets, filmmakers, and engineering designers, and initial findings suggest strong patterns of resemblance across the domains.

The idea of moving toward the sweet spot soon leads to a raised awareness of the various tools and techniques that may support this ambition. Once again, there is an immediate need for clarification of terms presented by the tools used. Efforts would likely include multidimensional mapping of creative processes, as well as the specific tools employed to handle constraints in various domains and contexts. (Stokes, 2007; Stokes, 2009) has taken steps toward using constraints as a conceptual tool for ideation in line with inspiration catalogues by (Koberg, Don & Bagnall, 2003; Michalko, 2006) and others. However, the development of more data-based studies such as (Biskjaer et al., 2010; Silva, 2010; Onarheim, 2012) and recently (Martin & Hanington, 2012), to name a few examples, would be most welcome.

Handling constraints and requirements is described as consisting of four fundamental activities: a) *finding* constraints in the problem; b) *constructing* constraints by looking outside the problem; c) *translating* constraints into different forms and exploring their implications; and d) *resolving* contradicting constraints (Stacey 2010). In our view, this basic four-parted distinction serves as a well-suited launch pad for further studies to gain insights into proficient ways to balance constrainedness.

4.2. The Search for the Sweet Spot

As mentioned, constraints can both impede (restrain) and enhance (enable) creativity, and either ‘too much’ or ‘too little’ constrainedness can bear a negative influence on creativity. (Joyce, 2009b) relates the two extremes to previous research showing how too much constraint pressure decreases motivation to create, and how too little constraint pressure can

be related to the well known paradox of choice, according to which an abundant array of options with no obvious ways to delimit them renders the individual slightly bewildered and unable to decide on how to proceed (see e.g., Schwartz, 2005). Similarly, (Amabile, 1996) refers to various studies showing differences in creativity scores under different testing conditions and time constraints, and (Csikszentmihalyi, 1997) describes how freedom can increase the experience of *flow*, but only until a certain level.

Figure 1 and 2 in section 3 have been developed from various observations of ways of balancing constraints as part of a search for the ‘right’ amount of constrainedness conducive to (optimum) creative performance. Even though the level of constrainedness needed to find the sweet spot cannot be generalized, we believe that studying the act of balancing constraints can be a rewarding new path for future creativity research. It should be investigated whether strategies for reducing and increasing constrainedness can be observed outside of engineering design, where most of the above notions origin, and to what extent creative practitioners in other domains also seem to embark on a search for the ‘right’ amount of constrainedness. If such patterns can in fact be discerned, the creative behavior related to balancing constraints should be investigated with a focus on if, and when, the total constrainedness is reduced or increased, and whether creative practitioners seem to be engaging in this in sequence or in parallel. Also, it should be studied if the search for a sweet spot is a conscious, intentional strategy, and if there are differences between experts and novices in terms of desired constrainedness and their strategies for manipulating constraints.

Based on the work presented, the messiness of real-world sets of constraints inarguably presents a challenge with regard to investigating particular constraints and their effect on creative processes and outcome. Not only are many constraints tightly related, they might even be conflicting. In our view, creativity seems tightly entwined with situations where articulated or unspoken rules are meaningfully broken, while at the same time the domain or ambient culture accepts the violation of the old and the establishment of new rules (Csikszentmihalyi, 1994; Simonton, 2004). This does not mean that there is a vacuum of rules; rather that a new set of rules soon replaces the old ones (Li, 1997). From a research perspective, these observations raise questions regarding the specific nature of the trade-off between seemingly incompatible or opposing constraints, as well as questions concerning the (possible) absoluteness and abstraction of constraints. What is especially interesting are situations in which constraints contradict each other during problem solving or otherwise impede the individual agent’s or team’s ability to produce a solution. In such cases each creative agent is confronted with a cognitive impasse, and the constraint elimination process comes into play, allowing the agent to reject a particular constraint to reach a solution (Chevalier & Ivory, 2003; see also (Stacey & Eckert, 2010) on contradicting constraints). Relating the above notions to the well known understanding of creativity as the combination of novelty and usefulness (Lubart, 1994; Sternberg & Lubart, 2009), we see the notion of constraints and constraint satisfaction as closely related to the question of usefulness.

5. Concluding Remarks

There is a lot of exciting work to be carried out in terms of reaching a better understanding of the impact and function of constraints in creative processes. Although all creative activities entail numerous choices, be it writing romantic poems for Valentine’s Day or designing medical equipment, not all of these choices surface in the agent’s consciousness – and luckily so. Being forced to constantly reconsider all one’s hard-gained knowledge and sensibilities would undoubtedly seriously impede all creative initiative. Allegedly more abstract notions

such as inspiration and insight moments are fortunately still seen an essential part of creative processes. In this chapter we have argued for the need for more transparency in the terminology related to the entwinement of creativity and constraints, and within this perspective we have proposed a number of new conceptualizations, among them ‘creativity constraints’, ‘balancing constraints’, and ‘the sweet spot’. Far from being exhaustive, we hope that these concepts may help see some of the current issues and challenges within creativity research in a new light, e.g., the notion of ‘inspiration’ as an immediate placement in the sweet spot with just the ‘right’ amount of constrainedness affixed to the creative challenge at hand. In our view, an even stronger cross-disciplinary focus on the entwinement of creativity and constraints than what recent seminal work has begun to suggest (Kaufman & Sternberg, 2010), may give rise to exciting new insights into creative processes regardless of domain or level of aptitude. With this chapter, we hope that our conceptual contributions have made such new paths for creativity research a little bit more accessible.

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References

- Ajit, S., Sleeman, D., Fowler, D. W., & Knott, D. (2008). Constraint capture and maintenance in engineering design. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing*, 22(04), 325-343.
- Amabile, T. (1996). *Creativity in context*. Boulder, CO.: Westview Press.
- Amabile, T. M. (1998). How to kill creativity. *Harvard Business Review*, 76(5), 76-87.
- Andrews, C. (2003). Constraint and convention: The formalism of the oulipo. *Neophilologus*, 87(2), 223-232.
- Anthony, S. D., Johnson, M. W., & Sinfield, J. V. (2008). Institutionalizing innovation. *MIT Sloan Management Review*, 49(2), 45-54.
- Baer, M. & Oldham, G. R. (2006). The curvilinear relation between experienced creative time pressure and creativity: Moderating effects of openness to experience and support for creativity. *Journal of Applied Psychology*, 91(4), 963.
- Ball, L. J., Onarheim, B., & Christensen, B. T. (2010). Design requirements, epistemic uncertainty and solution development strategies in software design. *Design Studies*, 31(6), 567-589.
- Biskjaer, M. M. & Halskov, K. (under review). Decisive constraints as a creative resource in interaction design and beyond**.
- Biskjaer, M. M., Dalsgaard, P., & Halskov, K. (2010). Creativity methods in interaction design. In *Desire '10: Proceedings of the first conference on creativity and innovation in design*. Aarhus, Denmark.
- Biskjaer, M. M., Onarheim, B., & Wiltchnig, S. (2011). The ambiguous role of constraints in creativity: A cross-domain exploration. In *Proceedings of the first design, development and research conference, 26-27 september 2011, cape town, south africa*.

- Bonnardel, N. & Marmèche, E. (2005). Towards supporting evocation processes in creative design: A cognitive approach. *International Journal of Human-Computer Studies*, 63(4-5), 422-435.
- Chevalier, A. & Ivory, M. Y. (2003). Web site designs: Influences of designer's expertise and design constraints. *International Journal of Human-Computer Studies*, 58(1), 57-87.
- Cross, N. (2004). Expertise in design: An overview. *Design Studies*, 25(5), 427-441.
- Csikszentmihalyi, M. (1994). The domain of creativity. In D. H. Feldman, M. Csikszentmihalyi, & H. Gardner (Eds.), *Changing the world*. (pp. 135-58). Connecticut, USA: Praeger.
- Csikszentmihalyi, M. (1997). *Creativity: Flow and the psychology of discovery and invention*. New York, USA: Harper Perennial.
- Darke, J. (1979). The primary generator and the design process. *Design Studies*, 1(1), 36- 44.
- Darlington, D. (2002). *Cognition and the engineering design requirements*. PhD, University of Bath, UK.
- Dorst, K. & Cross, N. (2001). Creativity in the design process: Co-evolution of problem-solution. *Design Studies*, 22(5), 425-437.
- Glück, J., Ernst, R., & Unger, F. (2002). How creatives define creativity: Definitions reflect different types of creativity. *Communication Research Journal*, 14(1), 55-67.
- Goldratt, E. M. (1990). *Theory of constraints (TOC)*. Croton-on-Hudson, NY, USA: North River Press.
- Gross, M. D. (1986, February). *Design as exploring constraints*. PhD thesis, Massachusetts Institute of Technology, USA.
- Guilford, J. P. (1950). Creativity. *American Psychologist*, 5(9), 444-454.
- Hull, E., Jackson, K., & Dick, J. (2011). *Requirements engineering* (3rd ed. ed.). London; New York: Springer.
- Isaak, M. I. & Just, M. A. (1995). Constraints on thinking in insight and invention. In R. J. Sternberg & J. Davidson (Eds.), *The nature of insight*. (pp. 281-325). Cambridge, Massachusetts, USA.: MIT Press.
- Johnson-Laird, P. N. (1988). Freedom and constraint in creativity. In R. J. Sternberg (Ed.), *The nature of creativity: Contemporary psychological perspectives*. (pp. 202-19). Cambridge University Press, NYC, USA.
- Joyce, C. K. (2009). *The blank page: Effects of constraint on creativity*. In *The blank page: Effects of constraint on creativity (dissertation)*. Thesis, University of California, Berkeley.
- Jul, S. (2004). *From brains to branch points: Cognitive constraints in navigational design*. In *From brains to branch points: Cognitive constraints in navigational design (dissertation)*. Thesis, Computer Science and Engineering, The University of Michigan. Retrieved January 26, 2011, from the Google Scholar database.
- Karau, S. J. & Kelly, J. R. (1992). The effects of time scarcity and time abundance on group performance quality and interaction process. *Journal of Experimental Social Psychology*, 28(6), 542-571.
- Kaufman, J. C. & Sternberg, R. J. (2010). Constraints on creativity: Obvious and not so obvious . In J. C. Kaufman & R. J. Sternberg (Eds.), *The cambridge handbook of creativity*. (pp. 467-82). Cambridge ; New York: Cambridge University Press.
- Koberg, Don & Bagnall, J. (2003). *The universal traveler*. Menlo Park, California: Crisp Learning.
- Lawson, B. (2006). *How designers think: The design process demystified*. Oxford; Burlington, MA: Elsevier/Architectural.
- Lewandowski, J. (2007). Boxing: The sweet science of constraints. *Journal of the Philosophy of Sport*, 34(1), 26-38.

- Li, J. (1997). Creativity in horizontal and vertical domains. *Creativity Research Journal*, 10(2-3), 107-132.
- Liikkanen, L. A., Björklund, T. A., Hämäläinen, M. I., & Koskinen, M. P. (2009). Time constraints in design idea generation. In *ICED'09 - international conference on engineering design*. Stanford University, California.
- Lubart, T. I. (1994). Creativity. In R. J. Sternberg (Ed.), *Thinking and problem solving*. (pp. 289-332). San Diego, CA: Academic Press.
- Maiden, N., Gizikis, A., & Robertson, S. (2005). Provoking creativity: Imagine what your requirements could be like. *IEEE Software*, 21(Sept./Oct.), 68-75.
- Mamykina, L., Candy, L., & Edmonds, E. (2002). Collaborative creativity. *Communications of the ACM*, 45(10), 96-99.
- Martin, B. & Hanington, B. M. (2012). *Universal methods of design: 100 ways to research complex problems, develop innovative ideas, and design effective solutions*. Beverly, MA, USA.: Rockport Publishers.
- Mednick, S. A. (1962). The associative basis of the creative process. *Psychological Review*, 69(3), 220-232.
- Michalko, M. (2006). *Thinkertoys: A handbook of creative-thinking techniques* (2nd. ed.). Berkeley, California.: Ten Speed Press.
- Negus, K. & Pickering, M. (2004). *Creativity, communication and cultural value*. London: Sage Publications Ltd.
- NN (2003). The free dictionary: Constrain. (The Free Dictionary by Farlex - an online encyclopedia/thesaurus) [Web page]. Retrieved April 25, 2011, from <http://www.thefreedictionary.com/constrain>
- Nuseibeh, B. & Easterbrook, S. (2000). Requirements engineering: A roadmap. In *Proceedings of the conference on the future of software engineering*.
- Onarheim (2012). Creativity from constraints in engineering design: Lessons learned at coloplast. *Journal of Engineering Design*, 23(4), 323-336.
- Onarheim, B. & Christensen, B. T. (2012). Distributed idea screening in stage-gate development processes. *Journal of Engineering Design*, 23(9), 660-673.
- Onarheim, B. & Wiltschnig, S. (2010). Opening and constraining: Constraints and their role in creative processes. In *Desire '10: Proceedings of the first conference on creativity and innovation in design*. Aarhus, Denmark.
- Perry-Smith, J. E. & Shalley, C. E. (2003). The social side of creativity: A static and dynamic social network perspective. *The Academy of Management Review*, 28(1), 89-106.
- Reitman, W. R. (1964). Heuristic decision procedures, open constraints, and the structure of ill-defined problems. In M. W. Shelley & G. L. Bryan (Eds.), *Human judgments and optimality*. (pp. 282-315). New York, USA: Wiley.
- Richard, J. -F., Poitrenaud, S., & Tijus, C. (1993). Problem-solving restructuration: Elimination of implicit constraints. *Cognitive Science*, 17(4), 497 - 529.
- Schwartz, B. (2005). *The paradox of choice: Why more is less*. New York: Ecco.
- Silva, P. A. (2010). BadIdeas 3.0: A method for creativity and innovation in design. In *Desire '10: Proceedings of the first conference on creativity and innovation in design*. Aarhus, Denmark.
- Simonton, D. K. (2004). *Creativity in science : Chance, logic, genius, and zeitgeist*. Cambridge, UK ; New York: Cambridge University Press.
- Stacey, M. & Eckert, C. (2010). Reshaping the box: Creative designing as constraint management. *International Journal of Product Development*, 11(3), 241-255.
- Sternberg, R. J. & Kaufman, J. C. (2010). *The cambridge handbook of creativity*. Cambridge ; New York: Cambridge University Press.

- Sternberg, R. J. & Lubart, T. I. (2009). The concept of creativity: Prospects and paradigms. In R. J. Sternberg (Ed.), *Handbook of creativity*. (pp. 3-15). Cambridge, U.K.: Cambridge University Press.
- Stokes, P. D. (2006). *Creativity from constraints: The psychology of breakthrough*. New York: Springer Publishing Company.
- Stokes, P. D. (2007). Using constraints to generate and sustain novelty. *Psychology of Aesthetics, Creativity, and the Arts*, 1(2), 107-113.
- Stokes, P. D. (2008). Creativity from constraints: What can we learn from motherwell? From modrian? From klee? *The Journal of Creative Behavior*, 42(4), 223-236.
- Stokes, P. D. (2009). Using constraints to create novelty: A case study. *Psychology of Aesthetics, Creativity, and the Arts*, 3(3), 174-180.
- Stokes, P. D. & Fisher, D. (2005). Selection, constraints, and creativity case studies: Max beckmann and philip guston. *Creativity Research Journal*, 17(2), 283-291.
- Ward, T. B., Smith, S., & Finke, R. (1999). Creative cognition. In R. J. Sternberg (Ed.), *Handbook of creativity*. (pp. 189-212). Massachusetts, USA: MIT Press.
- Warr, A. & O'Neill, E. (2005). Understanding design as a social creative process. In *Proceedings of the 5th conference on creativity & cognition*. April 12-15, 2005, London, UK.