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Decisive constraints as a creative resource in interaction design

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Abstract

This article explores the observation that highly limiting, creative decisions of voluntary self-binding that radically prune the design solution space may in fact fuel and accelerate the process toward an innovative final design. To gain insight into this phenomenon, we propose the concept '*decisive constraints*' based on a review of current, but dispersed, studies into creativity constraints. We build decisive constraints on *two definitional conditions* related to *radical decision-making* and *creative turning points*. To test our concept analytically and ensure its relevance to creative practice, we apply the two definitional conditions to three media façade installation projects in which our interaction design research lab has been involved. In accord with insights from these case analyses, we argue that decisive constraints may inform current research into design processes and act as a creative resource for practitioners, not only in interaction design but, we assume, also across related creative domains and disciplines.

Keywords: interaction design, creativity, constraints, decisive, media façades

1 Introduction

The main goal of this article is to better understand *constraints* in creative practice. More specifically, we are interested in the various ways in which constraints affect the progression of a design process. In its narrowest form, constraints tend to be perceived simply as requirements or demands; however, experienced creative practitioners are well aware of the complex, dual role of constraints: constraints both restrain and impede *and* enable and advance a creative course such as a design process. Rather than seeing constraints as problems or obstacles that a creative agent, in this case a designer, must work against or work around, we argue that the *enabling* property of constraints in creative practice be studied more in depth. Exploring this characteristic of constraints in creativity entails several core research questions. Can a design process be improved by applying an optimum amount of constraint pressure on the agent(s) at a given stage—neither too few nor too many constraints? Are some constraints, such as material, timeframe, budget, etc., more dominant or subordinate at various stages? And if so, why? When and to what extent should constraints be treated as flexible or fixed, soft or hard?

Balancing or managing constraints in a reflective, constructive manner toward a final design appears to be a feature of most design-related disciplines (Gross 1986; Onarheim 2012b), and, speaking in a computational/artificial intelligence

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(AI) perspective, Chandrasekaran (1990, 65) even goes so far as to argue that: '[formally], all design can be thought of as constraint satisfaction, and one might be tempted to propose global constraint satisfaction as a universal solution for design'. The importance of constraint satisfaction is also explored by Thagard and Verbeurgt (1998), who conceive it as a question of maximising coherence among elements in a computational process. Although constraints at a basic level of definition may be considered as 'limitations on action [that] set boundaries on solutions' (Vandenbosch and Gallagher 2004, 198), the conceptualisation, analytical and practical usage of the term are far from unanimous in design, let alone across other creative domains and disciplines. (We subscribe to a broad definition of 'domain' as a well-developed area of expertise with consensual performance criteria [Abuhamedeh and Csikszentmihalyi 2004, quoted in P.D. Stokes 2007, 109]. See also Li [1997, 109] on domains as 'bodies of disciplined knowledge'). Similarly, we consider 'discipline' a 'specialized . . . branch . . . of knowledge' [Stember 1991, 3]). This palpable conceptual discrepancy is not necessarily a problem as long as the scope of the studies is domain-specific; however, it poses a problem for furtherance of theory and knowledge interchange between research ventures into various kinds of constraints and their effect on creative agency and processes.

In our work we have become increasingly aware of the need for a more refined theorisation of balancing constraints. As opposed to advanced problem-solving in the tradition of the seminal work by Reitman (1964), Simon (1973), and Simon and Newell (1972), which is grounded in artificial intelligence systems and computational processes, *skilfully balancing constraints*, as we construe it, means the ability to realise, define and act upon circumstances and conditions in a creative process that are either unfavourable and delimiting or beneficial and emancipatory, depending on each agent's aptitude, experience and reflective choice of perspective. As the term 'constraint' is highly inclusive, aspirations to provide an exhaustive typology of constraints are doomed to fail. Thus, we deem it more fruitful to ground our research more narrowly in a domain into which we have gained insight over a number of years and then gradually extend the scope to tentatively reach out to other creative disciplines as well.

Due to its reliance on digital technology, *interaction design* is rich in terms of technological conditions, requirements and circumstances that enmesh the agents' freedom of action during a creative process. In the interaction design projects our research lab, CAVI, has run and been involved in (see Halskov 2011), it has become apparent to us that certain creative decisions have come to bear a particularly strong impact on the outcome. We have noticed that certain intentional creative moves that seem counterintuitive or even unwise, as they render the design process significantly more difficult by going against tacit knowledge and standard or first choices, thus pruning the solution space dramatically, in fact turn out to be related to the attainment of radically new solutions. This means that these freely installed creative obstructions share (at least) two key characteristics. They are rooted in *radical decision-making* by going against easy and common creative choices as solution alternatives, and they *accelerate the design process* by pushing it forward in the form of an unexpected leap. In an attempt to understand this, in our view, intriguing phenomenon, we have turned to research into constraints and constraint typologies related to creative processes. Based on reviews of previous and, primarily, current literature, we argue for the need for a new analytical concept to address this phenomenon of counterintuitive creative decisions and their observed relation to radically new design solutions.

Our proposal is *decisive constraints*, which builds on *two definitional conditions* that each refers to one of the two key characteristics mentioned above, namely radical decision-making and creative turning points. Installing seemingly highly inexpedient constraints in expectance of a more original final outcome may at times affect the design process so significantly that this obstructive act leads to an unforeseen, qualitative forward leap. It is this *decisiveness* that our

proposed concept aims to capture. Thus, we argue that decisive constraints may serve as an analytical tool to help convey new insights into creative processes, here focusing on interaction design. Furthermore, we contend that decisive constraints may be embraced as a rich, inspirational resource for the agent(s) involved. To be able to present this argument with due attention to theories of constraints in creative processes while also ensuring relevance to creative practitioners, the remainder of the article is structured as follows.

In Section 2 below, we flesh out the theoretical background. We begin by discussing key aspects of research into constraints and constraint typologies specifically related to human agency and creative processes. Our focus will be the arguably three main contributions to current theory. Although rich, the lineage of constraint studies is rather dispersed, so one way to help join together these conceptualisations is by the term 'creativity constraints'. We will briefly outline this concept before presenting the complex role of constraints as both creative enablers and restrainers. This comprises the first part of Section 3, which then focuses on the properties of voluntary, self-imposed creativity constraints with regard to decision-making and qualitative forward leaps in the design process. This second part of Section 3 features our core contribution, the analytical concept decisive constraints, which is built on *Definitional Conditions 1* and *2*. In Section 4, we test the potential of our analytical concept by applying the two definitional conditions to three media façade installation projects in which our interaction design research lab, CAVI, has been involved. We would like to stress that our concept *decisive constraints* is not a direct derivative of these three case examples. If that were the case, applying the concept to the same empirical data would imply a logical fallacy (circular reasoning). Rather, in addition to putting some 'meat' on our analytical concept, so to speak, revisiting these case examples yields the opportunity for new insights into the design processes and some of the varied ways in which the final designs came into being. Also, this strategy serves to ground our theoretical contribution in practice. The three projects consist of a proposal for a new art museum in Warsaw (2007), an urban interactive installation, Aarhus by Light (2008) and the Danish EXPO 2010 pavilion. In Section 5, we end the article by discussing potential next steps for interaction design theory based on our proposed concept and the two definitional conditions. Applying decisive constraints is not without costs and drawbacks, which we also briefly touch upon; however, we argue that decisive constraints may indeed also act as a creative resource for interaction design practitioners, provided the agents approach the process and apply the concept with adequate attention and reflection. Insofar as practitioners always face numerous challenging constraints in any creative process, we briefly present the idea that using decisive constraints as a means to leverage some of these challenges holds a distinct potential that reaches beyond interaction design and into other creative domains and disciplines. Finally, we briefly present a set of conclusions in Section 6.

2 Theoretical background

2.1 The ubiquity of constraints in design and the lack of a shared concept

No matter if a design process springs from a detailed task assignment, a design brief, as requested by a client, or comprises playful activities with no deadlines or fixed structure, all creative initiatives rely on decision-making. Options and choices are integral to creative progression. Some processes are marked by unmalleable requirements, often costs, deadlines, materials, fonts, language, measures, functionality, etc., meticulously stated in the design brief. Other activities rely less obviously on such constraints. To give an example: a designer is asked to make a prototype of a casing for a tablet computer and is initially free to choose between two types of material: aluminium or polycarbonate/acrylonitrile butadiene styrene (or, to avoid this tongue-twister, PC/ABS), which is frequently used in mobile phone bodies. Palpable constraints that the designer must handle will then typically include a variety of materials, deadlines, costs,

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measures, etc. Such constraints are usually synonymous with *requirements*. Since the designer is given two options in terms of material, aluminium or PC/ABS, (s)he must decide which material (s)he prefers. By choosing one material at the expense of another, (s)he necessarily constrains (her)himself, as each material has its own fixed set of measurable properties such as breaking stress, colourfastness, bulk density, thermal conductivity, etc. (S)he thus cuts off a range of the solution space, and the design must now comply with the fixed properties, desirable or not, of the chosen material. So while the specific choice clearly prunes the designer's creative space of action, the solution space, it also ensures the project's progression toward a final design. This conceptualisation of a co-evolution of problem and solution spaces in design can be traced back to the seminal work by Reitman (1964) and Simon (1973), which we return to shortly. More recently, the topic has been treated in detail by Maher and Poon (1996), Dorst and Cross (2001), Christensen, Onarheim and Ball (2010) and Wiltschnig, Christensen, and Ball (2013).

As this example suggests, a designer will usually approach a given task with an open mind-set to sustain as many possible courses of action as possible. This is especially true for expert designers as opposed to novices (Cross 2004), as the former seem more aware of carefully selecting the best-suited cognitive approach to the problem at hand (Kavakli and Gero 2002). This does not imply that we see design as a predominantly explicit rational endeavour in the tradition of Simon (1996). Rather, tacit moves are indeed integral to all design activities. The points we wish to make are, first, that constraints are always a part of a creative activity regardless of their origin—be it externally imposed requirements of a design brief, properties of the design material or aesthetic or other preferences or de-selections freely chosen by the designer (her)himself; and, second, that there are various strategies for the designer to approach this ubiquity of constraints. Although there is a general agreement on the presence of constraints in design, there is a palpable lack of terminological consensus in constraint research among designers and scholars (Onarheim and Wiltschnig 2010). Given the vast array of disciplines that may be subsumed under the generic heading 'design', this terminological cloudiness is to be expected. The problem, however, is that it makes it harder to attain immediate furtherance of theory across various disciplines in terms of research into constraints pertaining to creative processes.

An example of this cloudiness can be seen from the Palo Alto-based design company IDEO's theme-based, free-form initiative, Designs On— :

> *Designs On— is, at its core, a flexible forum that drives exploration, iterative thinking, early prototyping, and sharing,* minus boundaries or constraints. (http://designs-on.com, emphasis added).

What IDEO consider a constraint-free arena for creative agency in its view of design thinking (Brown 2008; Brown and Katz 2009) we would call a creative environment with *no externally imposed* constraints. By applying a practically attuned, finely meshed, conceptual awareness to constraint management, we believe the resourcefulness of constraints in interaction design and related creative disciplines may be exposed and studied in a more fruitful way. That means taking more philosophically inclined questions of agency and decision-making into account as well.

2.2 Overview of current constraint research

2.2.1 Etymology and lack of detailed, generic constraint typologies

Although the term 'constraint' can be traced back to its Latin form as the verb 'constringere' meaning to 'restrain, compress, bind or press together' (Farlex, *The Free Dictionary*: constrain), a proper academic conceptualisation of the term has only been attempted in recent years. It is difficult to establish a single starting point for constraint research; however, Reitman's (1964, 1965) work on the structure of ill-defined as opposed to well-defined problems may arguably be seen as one of the first key contributions. Reitman's interest is problem analysis aimed to

be compatible with computer programming languages, and through a series of expositions he argues for a continuum ranging from well-defined formal problems to ill-defined ones such as composing a fugue (1964, 300–301). In his view, ill-structured problems are based on *open constraints*:

> *whose definition includes one or more parameters the values of which are left unspecified as the problem is given to the problem-solving system from outside or transmitted within the system over time . . . Open constraints are ubiquitous . . . [they] provide definitional slack. They allow the problem solver to take a new tack on his problem,* not by violating his constraints (though he may of course do that too)*, but by adjusting those parameters of the constraint that are open to him* (Reitman 1964, 292–293, emphasis added).

(We will return to the violation part of this quote shortly). In other words, an ill-defined problem does not accommodate an obvious solution path due to insufficient information available to the problem solver, and this calls for novel solutions. Simon (1973) builds on Reitman's broadly conceived notion of constraints as 'any or all of the elements that enter into a definition of a problem' (Simon 1973, 189), but stresses the lack of a clear *structure* of such problems (hence his term 'ISP' as an abbreviation of 'ill-structured problems'). As a concept, therefore, constraints become integral in the work of both Reitman and Simon; especially with regard to design, as Simon asserts that '[d]esign solutions are sequences of action that lead to possible worlds satisfying specified constraints' (Simon 1996, 124).

While Reitman (1964, 1965) and Simon (1996, 1973) use the term 'constraint' in a specific way, the easy adaptability of the term itself has enabled contributions from a number of domains, all of which may be subsumed under 'constraint research' in the widest sense. These contributions range from metaphysical theory (Harré 1970), philosophy of sports (Lewandowski 2007), literary history (Andrews 2003), creative end user development (Coughlan and Johnson 2007, 2008), engineering (Nuseibeh and Easterbrook 2000) to management philosophy (Goldratt 1990) and artificial intelligence (Stefik 1981; Boden 2004, 1999), and even leisure research (Damali and McGuire 2013) to name just a few examples. The lack of terminological consensus across this body of work is no surprise given the spaciousness of the term itself. It is most likely also a reason why there have been few attempts at providing detailed, generic typologies of constraints and their effect on human agency, be it creative endeavours or not. With no clearly defined conceptual scope, typological efforts soon skid toward the insuperable problem the Cartographers Guild bring upon themselves in Jorge Luis Borges' famous one-paragraph short story, 'On the Exactitude of Science' (2004), in which he fabulates about an empire's ambition to map the entire world in all its detail 1:1. The empire's map expands to an extent that renders it unusable, whereby Borges elegantly depicts the dilemma of accurate scientific representation.

The main body of current research into constraint typologies specifically pertaining to human agency and creative processes is rooted in contributions from three disciplines—architecture, psychology and philosophy—and is based on work by individual scholars. Having established the seminal work of Reitman (1964) and Simon (1996, 1973) as the argued starting point(s) for current constraint research, we review the most recent main contributions in order to outline the conceptual backdrop for our own work.

2.2.2 A cubic constraint typology for architecture

According to American architect Frank O. Gehry, constraints are a crucial part of the way architects conceive of their work process (Boland et al. 2008). Currently, the architectural community's main contribution to constraint typology research is a three-dimensional cube-like model of constraints related to design problems (Lawson 2006, 106). Based on his experience as an architect and a psychologist, Bryan Lawson's model comprises three axes, which we in the present context will denominate X, Y and Z. The cube's X axis illustrates the distinction between (a)

internal and (b) external constraints. The former refers to the relationships between elements of the object being designed, whereas the latter denotes contextual factors such as the site, location or specific context in which a given design is to be used (98). The vertical Y axis outlines the four main generators of constraints according to Lawson, namely (a) legislators, (b) users, (c) clients and (d) designers. The last axis, Z, groups constraints into four types: (a) radical; (b) practical; (c) formal; and (d) symbolic. Although Lawson's model opens up new paths of inquiry, a more elaborate discussion of the elements of his constraint typology is beyond the scope of this article. Suffice it to say that while this model of thirty-two boxes is useful to disseminate *in vivo* architectural design problems by *locating key challenges*, the very same domain specificity impedes immediate and seamless furtherance of theory across disciplines. However, the main reason why Lawson's constraint typology model cannot address the key characteristics of decision-making and turning points that we are aiming to capture and conceptualise here is the static nature of his cube-like model. More precisely, his model, by definition, is not suited to address the dynamic correlativity of the variables, i.e. how constraints affect a design process over time (diachronically).

2.2.3 Dichotomous constraints as a pathway to creative breakthrough

Another creativity-oriented constraint typology is offered by psychologist Patricia D. Stokes (2006). In her work, she attempts to bridge several domains of creative practice, such as literature, visual art, fashion, architecture, music and, more mundanely, advertising, in which she has previously worked. P.D. Stokes's model is a problem-solving model, which builds directly on the pioneering work by Reitman (1964, 1965) and Simon (1996, 1973). From Reitman, P.D. Stokes incorporates the idea that paired constraints direct and limit search in a problem space, and from Simon, that search can only lead to novel solutions if the problem space is ill-structured (P.D. Stokes 2009, 174). This is the basis for her creative problem-solving model. The general premise is the idea that artistic creation is about solving 'the creativity problem':

> *the creativity problem is* strategic *and* structural. *It involves selecting (the strategy part) paired constraints (the structure part) that preclude reliable, successful responses and promote novel, surprising ones* (P.D. Stokes 2009, xiii, emphasis in original; see also Reitman [1964, 289] on 'creative problems').

This, she argues, is the most used and useful way to solve 'the creativity problem'. By studying the emergence of Cubism and other artistic breakthroughs, she presents the idea of a unique, dichotomous pattern as the basis of such *qualitative forward leaps*. In several chapter subheadings (see also P.D. Stokes 2007, 2008, 2009; P.D. Stokes and Fisher 2005), she denotes the finding as a question of what can be learned from a pre-eminent, creative individual like Picasso or Stravinsky. Thus, she contends that the ability to create real breakthroughs can be learned—or better, *intentionally emulated*—by following a dichotomous constraint-based creative process model.

The premise for this argument is dual. First, she must provide a constraint typology to have a pool of constituents from which to choose. Hers is quartered with an emphasis on *goal constraints*:

> Goal constraints *are overall criteria. Accepted by a domain, they become stylistic conventions, answers to questions like 'is this a Fauve painting?' All other constraints are purposively picked to help realize the goal. These include* source constraints*, which supply stylistic elements for culling and recombination,* subject constraints*, which specify content or motif, and* task constraints*, which govern materials and their application* (P.D. Stokes and Fisher 2005, 283–284, emphasis in original).

Elsewhere, P.D. Stokes mentions domain, talent, variability and cognitive constraints (2006, 8), albeit with less clear conceptual demarcation. Assumingly, only domain constraints fit in her

process model. Second, to sustain logical consistency, P.D. Stokes must show that the creative agent has *intentionally* conceptualised his/her process dichotomously from the very outset using paired constraints; that is, she must prove a direct, legible link between the *intentional* act of freely selecting paired constraints and the *subsequent* achievement of creative breakthrough. The question remains to what extent this intended cause and effect-relation can be adequately demonstrated. In Weisberg's (2006, 2010) comparative studies of the revolutionary creation of the DNA double helix model from 1953 and Picasso's iconic 1937 painting, *Guernica*, he concludes that in both cases 'creative advances came about through the building of the new upon the foundation of the old. There was no wholesale rejection of the past, no "breaking out of the box"' (Weisberg 2010, 241). These observations seem to suggest that genuine creative breakthrough is *also* based on many other variables, including pre-reflective decision-making, applied tacit knowledge (and 'gut feeling') and systematic creative iterations, all of which challenges P.D. Stokes' core idea of breakthrough as (potentially) achieved directly through a carefully devised, strategic constraint selection and substitution process.

P.D. Stokes puts strong emphasis on a creative agent's ability to manage and manipulate his/her own creative process by using preclude–promote constraint pairs to restructure problem spaces so that novelty (here, breakthrough) becomes possible and probable. Certainly, this ensures great variability in the creative outcome, but it also greatly diminishes the whole idea of creative freedom, as artistic freedom thus consists solely in the reflective choosing of an agent's own constraints (P.D. Stokes and Fisher 2005). To be able to choose one's own constraints requires an extensive experience of and insight into one's domain, so logically this view entails that creative novices enjoy no creative freedom proper. This 'leaves artistic freedom to those experts who self-select and self-impose constraints on their currently successful solutions. Not all experts do. Not all experts can' (P.D. Stokes 2008, 12). Thus, according to the model, neither novices nor all creative experts can be said to enjoy creative freedom. In our view, this seems a somewhat drastic inference. Also, it raises the question of where creative playfulness, experimentation and spontaneity fit in within this problem-solving model of creativity. As for spontaneity, this is only accommodated by the model as 'skilled execution' such as improvisation by a jazz musician (P.D. Stokes 2009, 179). Sudden *radical experimentation* in the sense of doing something 'crazy' or foolish just for the sake of it in order to see what happens cannot, by definition, be captured by the model's conceptualisation of constraints in creative processes. Again, this seems a severe inference. The English zoologist E.R. Lankester once visited Charles Darwin, who explained to him an ongoing pollen experiment. Darwin had no idea how it would turn out: 'That's a fool's experiment. But I love fools' experiments. I am always making them' (Lankester 1896, 4391). Anecdote or not, this snippet suggests that playfulness and radical experimentation are also integral to creative processes. With regard to art, philosopher of aesthetics P. Livingston (2009) shares this view:

> *deliberate experimentation with seemingly arbitrary constraints is sometimes an important part of the story [i.e., artistic creation], and can indeed establish a scheme within which unanticipated yet viable aesthetic discernments become possible* (Livingston 2009, 146).

(See also Kaplan and Simon [1990] on 'experimental manipulation' of cues to constrain search within a problem space in order to attain an insightful solution). Thus, while P.D. Stokes's model of creative processes based on preclude–promote constraint pairs offers a beneficial framework for analysing and emulating advanced creative processes, it (logically) reserves 'genuine' creative freedom to only a select few expert practitioners, and it leaves little room for radical, playful—or even foolish—experimentation (such as expressed by Darwin) just for its own sake. The latter inference is the main reason why P.D. Stokes's constraint typology and model do not provide the conceptual foundation we need for the present purpose.

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2.2.4 A tripartition of constraints as a philosophical foundation

The most comprehensive theoretical contribution to constraint typology research focusing on human agency is offered by Elster (2000). In three long essays spanning philosophy of mind and practical rationality, political science and the creation of art, Elster modifies some of his earlier ideas of benefits from pre-commitment and self-binding (1984). His work involves three conceptualisations of what he generically calls 'beneficial constraints'. To locate where we position our own theoretical contribution within current constraint research pertaining to creative processes, as featured on Figure 1 below, it is necessary to briefly outline Elster's work. Elster's first typology is dual and comprises (1a) 'incidental constraints', which are constraints that *actually* benefit the constrained agent, but are not chosen by the agent (her)himself. As opposed to this, (1b) 'essential' constraints' are: 'constraints that an agent imposes on himself for the sake of some expected benefit to himself' (2000, 4). For our present purpose, Elster's concept of essential constraints, (1b), emphasising the agent's personal freedom and intentional actions, is most important.

In the third of the most recent essays, Elster (2000) explores the idea that various kinds of limitations can in fact enhance the aesthetic value of a work of art. In doing so, he probes into creativity and design research, although he never mentions this himself. According to Elster, constraints in art serve two ends: they focus the agent's attention; and they enhance the 'aesthetic potential' so that the normative goal of any artist is to: '*maximiz[e] aesthetic value under constraints*' (200, emphasis in original). This yields two additional conceptualisations of constraints. The first of these two is the more incisive and offers a clear and useful basic typology of constraint emergence by distinguishing between: (2a) *intrinsic*, (2b) *imposed* and (2c) *self-imposed constraints*. Intrinsic constraints (2a) refers to constraints given by the material; see fixed properties such as bulk density and breaking stress in the above example with the mobile phone body. Externally imposed constraints (2b) are various requirements and demands emerging from the given context, including outside stakeholders, e.g. a budget, a timeframe, demand for the use of a particular material, etc. The last type, self-imposed constraints (2c), builds directly upon Elster's notion of beneficial, essential constraints (1b). Unsurprisingly, self-imposed constraints stem from the agent's own voluntary choices such as a director's decision to shoot a (contemporary) movie in black and white.

Elster's third typology, the distinction between (3a) *hard* and (3b) *soft constraints*, is included here for the sake of completeness. Hard constraints (3a) denote formal, material, technical and financial constraints, and soft constraints (3b) refer to genres and conventions. Armed with these (ontological) typologies, Elster engages in acute observations and inductive inferences about the role of constraints in artistic practice as a creative domain. Despite concessional disclaimers of not being a specialist in the field, he states that he does not see aesthetic theory as a highly developed discipline (2000, 179). Such polemic stipulations in addition to a patently conservative aesthetic stance, an aversion to avant-garde art like the work of composer John Cage (which he calls 'entirely unserious . . . and a gigantic and successful put-on' [2000, 245]), and the conviction that art equals maximising aesthetic value have not exactly eased an appropriation of his ideas among scholars in the philosophy of aesthetics (for critiques, see Levinson [2003] and Livingston [2009]). One could speculate that these circumstances could be a reason why Elster's pioneering ideas and analyses of the benefits of voluntary self-binding, pre-commitment and constraints on human agency have not gained more attention in creativity research. His incisive aesthetic idiosyncrasies notwithstanding, we contend that Elster's three distinctions offer an acute and philosophically sound foundation for our exploration into constraints and decision-making and turning points. Elster analyses the (expected) benefits of self-binding—see (1a) and (1b)—provides an analytical tool to discern the most fundamental (ontological) aspect of constraints, i.e. how they

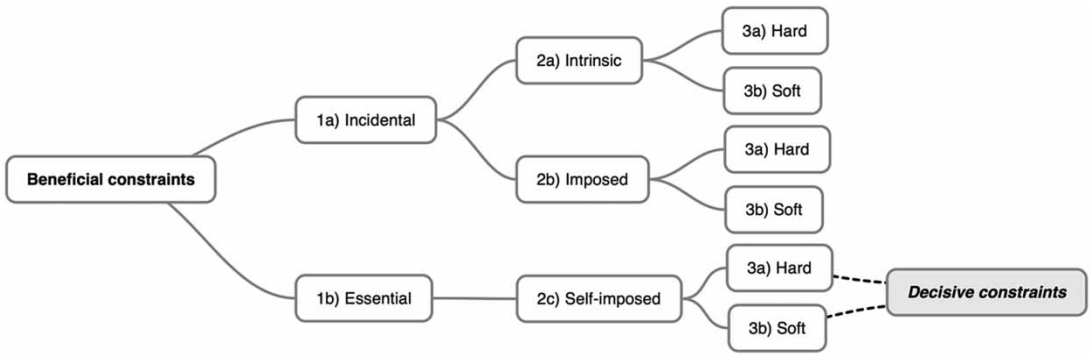

Figure 1. Decisive constraints in a generic constraint framework (based on Elster [2000]).

emerge—see (2a)–(2c)—and outlines a continuum of hard vs soft constraints and argues how neither of these labelled positions are fixed—see (3a)–(3c). So although Elster never decidedly focuses on design or creative processes, his insights and clear conceptualisations offer a solid foundation for our own concept, *decisive constraints*, which we will introduce shortly.

2.3 Toward a shared conceptual framework based on current constraint research

2.3.1 Two main paths in constraint research related to creative processes

The above presentation of key contributions to constraint typology research related to human agency and creative processes contain several distinctions and conceptualisations on both generic and sub-levels. To sum up these dispersed studies and highlight what we see as focal points in the current body of work based on the three main contributions, we have included Table 1. Far from being a normative judgment or a 'score', the table is only meant to convey a simplified overview of four main parameters in terms of research interests and aims within the three disciplines (stated as Low, Medium or High in terms of priority).

Our literature review including the focal points suggests (at least) two paths to pursue in an attempt to employ insights into constraints and constraint typologies to help leverage the current understanding of design processes in a perspective that is relevant to several disciplines. One is a cumulative list of various disciplines in which constraint modelling is thought to be of use. This is the case with P.D. Stokes' (2006) work, although collaborative forms of creative practice are missing, among them film-making and design. The other path is the philosophical one. Elster's (2000) scope is decidedly philosophical; however, he never claims to conduct creativity research, let alone design research, proper, which means that he does not explore key design topics such as design will, design intention and design principles. What he aims to ensure, though, is universal-oriented theoretical and conceptual consistency. This makes his work stand out from Lawson (2006) and P.D. Stokes (2006), whose scholarly contributions also seem informed by personal experience (Lawson in design, P.D. Stokes in advertising) and targeted at individual domains, whether it be one such or an entire listing. Rather than choosing one such path over another, we believe it is more fruitful to try to bridge the two; that is, to discern key elements and findings from each stance and use these valuable insights to inform advancements in a constraint-oriented understanding of design processes, in this case in interaction design in particular.

2.3.2 Bridging current contributions to help inform future research

In the projects that our interaction design research lab, CAVI, takes part in, we plan our work according to a research-through-design approach (Dalsgaard 2010; Halskov 2011; Basballe and Halskov 2012) inspired by ideas suggested by

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Focal points Disciplines	Inspiration from professional experience	Applicability to creative processes	Cross-domain relevance	Development of theory and concepts
Architecture *Industrial design*	HIGH	MEDIUM	LOW	LOW
Psychology *Problem solving*	MEDIUM	HIGH	HIGH	MEDIUM
Philosophy *Practical rationality*	LOW	LOW	HIGH	HIGH

Table 1. Focal points within current research into constraints related to creative processes.

Frayling (1993) and, recently, Koskinen et al. (2011) and Gaver (2012); for a critique, see Zimmerman, Stolterman, and Forlizzi (2010). This is based on the contention that grounding research in practice and personal experience is vital to the development of design theories. This means that we concur with Lawson's (2006) emphasis on working in *in vivo* settings to locate crucial challenges in the design process. Also, we share his view on the importance of personal experience and hard-won domain knowledge to conduct design research. As outlined, P.D. Stokes (2006) employs a cross-domain scope. Since 'constraint' in itself is a highly inclusive and diffuse term, such cross-domain considerations must be taken into account from the outset. Although P.D. Stokes emphasises her model's ability to promote variability, her notion of 'breakthrough' remains not quite clear. Understood narrowly (and pragmatically), it might just mean reaching a new solution path, but it seems hard to consider 'breakthrough' as sheer novelty, thereby ignoring the impact factor. P.D. Stokes never explains on what grounds 'breakthrough' can be assessed; nor does she address when, by whom and by which aesthetic standards it can be asserted. Assumingly, 'breakthrough' can only be assessed in retrospect. This brings Boden's (1999, 2004, 2010) notion of H-creativity (historical creativity), as opposed to P-creativity (psychological creativity), to mind. This opacity, however, does not alter the fact that P.D. Stokes's model and its prioritisation of novelty, variability and even breakthrough as the overarching goal (see her so-called 'goal constraints' [P.D. Stokes and Fisher 2005, 283–284]) is inspiring for our present purpose, and so is her notion of playing with or manipulating constraints to attain significant qualitative forward leaps in the creative process.

In our view, a fruitful way to proceed with the aim of strengthening the understanding of design processes via insights into ways of creatively balancing or manipulating constraints is a combination of (at least) three elements: the inspiring contributions from psychology and architecture; our personal experience and focus on grounding design research in practice; and, finally, the conceptual clarity offered by more philosophically inclined studies of constraints on human agency. This is where Elster's (2000) pioneering work is crucial, as he, his aesthetic idiosyncrasies notwithstanding, has developed the most illuminative constraint typology so far. For our present purpose, it is his acute tripartition of intrinsic, imposed and *self-imposed constraints*—see distinction (2a)–(2c) in Section 2.2.4)—which forms the foundation for our core contribution, i.e. the introduction of the concept *decisive constraints* as a creative resource. To illustrate this conceptual kinship and pinpoint where we see our own contribution to constraint research, we have included Figure 1, which gives an overview of Elster's intricate distinctions, as he does not provide such a visual representation himself.

Explicating current research into constraint typologies related to human agency and creative processes admittedly entails the risk of construing a field in a heterogeneous, segregated way, emphasising differences, not similarities. Given the inclusiveness of the term constraint itself, this

lack of shared scope in constraint typology research is to be expected. Rather than being a particular field, constraint typology research as of now is a cluster of various ideas and contributions with few shared citations or mutually transparent concepts, let alone cross-domain ties to the work of other peers. Linking this to design processes to help inform current studies and, potentially, help spur furtherance of theory and knowledge interchange between disciplines therefore requires a solid conceptual basis to avoid causing even more theoretical cloudiness. This is the reason behind our decision to provide the theoretical overview as featured above, and it with this in mind that we now proceed to propose *decisive constraints* as small step toward an improved understanding of design processes based on insights into constraints and their relation to decision-making and creative turning points.

3 Introducing *decisive constraints* as an analytical tool

3.1 Creativity constraints as restrainers and enablers

At the core of our research methodology lies the assumption that constraints may profitably be considered a resource in design and other creative disciplines if approached with an open mind and managed in an innovative, reflective manner. As argued in detail in Onarheim and Biskjaer (2013), we propose the generic term 'creativity constraints' to help draw together a wide selection of existing work investigating various aspects of constraints in relation to creativity: 'Creativity constraints are explicit or tacit factors governing what the creative agent/s must, should, can, and cannot do; and what the creative output must, should, can, and cannot be' (8). Based on this proposed definition, we will from now on use the term 'creativity constraints' rather than our previous, more wordy formulation. Following findings by Reitman (1964, 1965), Isaak and Just (1995), P.D. Stokes (2006, 2007, 2009), Joyce (2009), Onarheim and Wiltschnig (2010) and Biskjaer, Onarheim, and Wiltschnig (2011), creativity constraints possess a fascinating duality. They are both a hindrance/restrainer *and* a resource/enabler for creative agency. Speaking strictly in a problem-solving perspective, this is what P.D. Stokes refers to when she states that constraints both preclude and promote the structuring of a solution path through a problem space (2006, 2007, 2009). Also, this duality is in alignment with the profound studies of artificial intelligence and computational art and creativity conducted by Boden (2010): 'Constraints on thinking do not merely constrain, but also make certain thoughts – certain mental structures – possible' (2004, 58); and: '[f]ar from being the antithesis of creativity, constraints on thinking are what make it possible. This is true even for combinational creativity, but it applies even more clearly to exploration-based originality' (95). Given our research-through-design approach, Boden's notion of 'exploration-based originality' applies to our own understanding of one of the pivotal aims of design, not least interaction design, as this by definition involves one or more engaged agents in addition to the designers themselves. It should be noted that Boden in the above quotations does not address design in particular, but is concerned with creativity in a broad sense under which numerous research themes and disciplines are subsumed (Sternberg 1999; Sternberg and Kaufman 2010). As our core contribution is theoretical in scope, it is necessary to briefly consider the relationship between design and creativity while maintaining a focus on relevance for practice. This is the next step toward being able to offer a conceptualisation of the observation that some severely limiting creative decisions of voluntary self-restraint may be just the trick or knack that accelerates the design process quite dramatically and occasionally leads to breakthroughs in terms of a truly original creative outcome.

3.2 Creativity constraints and decision-making

As noted by Johnson-Laird (1988), clear-cut definitions of creativity are scarce and tend to be more beneficial when presented *after* a process or a study rather than at the outset. Given the myriad and diversity of contexts in which creativity appears, from needlework and baking recipes over

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filmmaking and music to educational policies and medical inventions, questions of individual skills (Gaut 2009), knowledge (Weisberg 1999), learning and education (Robinson 2011, Peterson et al. 2013), culture (Lubart 1999) and many more (Runco and Albert 2010) have all become vital components of current creativity research since Guilford's (1950) seminal inaugural presidential address to the American Psychological Association (APA). This thematic complexity holds true for constraint research as well. Rather than explore these relevant topics, we wish to focus attention on the design process conceived as a constraint-based, iterative progression toward a final design. Creativity scholars seem to agree that *decision-making* is essential to all creative activities: 'to be creative is to be free to choose among alternatives' (Johnson-Laird 1988, 202); and: 'the creative mind is [not] constrained to do only one thing. Even someone who accepts all the current constraints without modification will have a choice at certain points – sometimes, a random choice will do' (Boden 2004, 95). As these snippets emphasise, decision-making and constraints are closely interwoven. This is especially true for design, on which we will now focus.

The notion that creative activities in general can be conceptualised in terms of managing, or balancing, creativity constraints is mirrored in Stacey and Eckert's (2010) continuum of over-constrained problems (such as in engineering design) with very detailed design briefs stating exact deliverables vs under-constrained problems (essentially artistic creation), where the creative agent must impose various constraints on (him)-herself in order to be able to navigate his/her creative space of action (see also Reitman [1964, 300–301] on a continuum ranging from well-defined problems to ill-defined ones). Referring to this over- vs under-constrained continuum does not mean to suggest that all creative activities may be analytically exhausted using a rational problem-solving approach in the tradition of Simon (1996, 1973). Rather, as argued in detail elsewhere (Onarheim and Biskjaer 2013), the point we wish to make is that various creative domains feature various levels of constraint intensity or 'constrainedness'. This constrainedness may also be stated conversely as experienced degree of creative freedom. Following our above definition, a poet is subjected to fewer creativity constraints than an engineering designer asked to make a prototype of a low-cost cardiac pacemaker. In accordance with Elster's typology of intrinsic, imposed and self-imposed constraints—see (2a)–(2c) in Section 2.2.4—creativity logically entails *self-imposed constraints* in the form of *inescapable*, *intentional choices*. Choosing one thing—a material, a structure, a form, a size, a timeframe, etc.—over another is a prerequisite for the creative process to progress and not stall regardless of domain.

Here, 'intentionality' as deliberate, voluntary choices in a process may be observed across the entire spectrum of creativity research, from studies of the creation of art (Livingston 2007), via practical rationality and agency (Bratman 1999) to design. With regard to design, we subscribe to a generic understanding of design as a particular form of creative, human action based on 'intentional change':

> *Design will and design intentions are the means for initiating and directing change based on human agency. It is design will and design intention, guided by design judgment, that transform the abstractness of relevant scientific knowledge and other forms of knowledge into a final unique design, the ultimate particular. The ultimate particular is that which 'appears' in the world* (Nelson and Stolterman 2012, 32).

The important part here is how the transition from abstract to concrete, from idea to the ultimate particular, may be governed by the agent(s) involved. What these considerations suggest is that decision-making and creativity constraints are not only integral to all creative processes; they are also tightly interwoven, since they both rely on a creative agent's ability to make a free, intentional choice in the form of one or more self-imposed creativity constraints. This is especially evident in design, where the creative agent(s) must find innovative ways to balance the many intrinsic and imposed

creativity constraints stated in the design brief (see also Onarheim 2012a, 2012b). This *entwinement of decision-making and creativity constraints* is one of two reasons why we propose decisive constraints as an analytical concept for design research.

3.3 Creativity constraints and creative turning points

Although creativity constraints are conceptually (and thus ontologically) inseparable from decision-making, their impact on the progression of a design process varies greatly. Mundane choices such as ignoring a phone call or postponing a coffee until after a given task has been completed may not influence a process significantly. Other decisions bear more profound consequences on the outcome. A common way of framing such brief, intense events during which the creative process advances rapidly is by terms such as 'insights' (Isaak and Just 1995; Sternberg and Davidson 1995; Miller 2000; Wiltschnig and Onarheim 2010) or 'leaps' (Holyoak and Thagard 1996). Qualitative progressive leaps do not necessarily need occur for a process to be considered creative. Weisberg (1986) has shown that solutions to problems often come in gradual increments based on—and in extension of—past experiences. While this indicates the typical pattern, creative processes frequently also include brief events in which new ideas suddenly arise. One way to construe this is Boden's (1999) notion of transformation of conceptual spaces, which also aims to explain why some ideas are considered more radically new and original than others (Boden 2004, 94). Following Guilford and Paul (1967) and, more recently, Löwgren and Stolterman (2004, 29–30) among others, such intense phases can be described in terms of divergent and convergent thinking through which the problem space is radically redefined. Although serendipity may occasionally play a role in such events, thereby providing a solution without it being sought (Boden 2004, 234–237), most often *radical progression* is based on decisions made by the agent(s) involved.

With decision-making and creativity constraints being entwined, it is possible to map and track down various spurs of simultaneous idea-generation and decision-making in a process (Dalsgaard and Halskov 2012). As shown in a design study by Dalsgaard, Halskov, and Nielsen (2008), the participants make numerous decisions during a process, and some of these choices are so *radical* that they boost the progression of the design process remarkably by yielding new ideas, which thus enhance the solution space. What we have noticed over time in the various interaction design research projects that our lab has been involved in is that some of the choices leading to the most significant, creative progression of the design process are rooted in *counterintuitive*, *radically limiting self-imposed creativity constraints* that dramatically prune the design solution space. By generating *creative turning points*, these radical choices become crucial—or better, *decisive*—for the outcome of the design process. And this is the other reason for our proposition decisive constraints.

3.4 Decisive constraints as an analytical concept in design

3.4.1 Definitional condition 1: radical decision-making

As shown above, all creative endeavours, from art to engineering design, involve decision-making with some being mundane musings on lengths of coffee breaks. Choosing one over another in such instances entails but a minute limitation of the solution space, which most assumingly does not affect the remainder of the process in any significant way. Opting for five minutes extra mocha time, thereby reducing the remaining time available for the process ever so slightly, exemplifies what we propose to call a *trivial* self-imposed creativity constraint. Creative self-restraint in this puny, inconsequential sense, most often based on (pre-reflective) sudden impulses, is too vague as a concept to be of genuine interest as a means to inform the current understanding of design processes.

To counterpoint this mundane example, we wish to zoom in on particular instances where an agent makes a creative choice that seems

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completely at odds with conventional wisdom within the domain. By 'conventional wisdom', we mean the creative agent's personal experience, first choices, usual and standard solution alternatives in terms of his/her most accessible (tacit) knowledge resources, all of which govern what (s)he would normally choose to do without sudden hesitation or critical reflection. Such a strange, seemingly unwise or even foolish choice (see the above quote referring to Darwin's pollen experimentation) is what we attempt to capture conceptually by the term '*radical* self-imposed creativity constraint'. It is based on unpredictable, intransigent decision-making that renders the creative task at hand (at least seemingly) much harder to resolve. In their three-phase invention process model, which consists of design space limitation, design generation, and design analysis, Isaak and Just (1995) also focus on decisions to impose constraints. They argue that 'successful invention depends on imposing constraints on the nature of the invention during design space limitation and design analysis and on releasing or reformulating constraints during design generation' (285). We appreciate this varied use of constraints in a creative (here, problem-solving) process; however, our view on such impositions of constraints differs from theirs because we distinguish between *trivial* vs *radical* self-imposed creativity constraints. This distinction construed as a continuum with no clear-cut demarcations relies on tentatively assessed impact, tension and unpredictability. Therefore, it is also dissimilar from the continuum of strong (fixed) vs weak (flexible) constraints as suggested by Stacey and Eckert to state levels of malleability, i.e. to what extent the given constraints may be manipulated by the agent(s) involved:

> Weak *constraints can be relaxed to allow less ideal but feasible designs; conflicting* strong *constraints, that must be met, may make the problem impossible. Design problems are constrained both by explicitly formulated requirements and constraints, and by implicit assumptions about the form of the solution'*(Stacey and Eckert 2010, 249, emphasis added).

What interests us is the situation where a creative agent intentionally and with eyes wide open makes a completely unexpected creative choice that seems so counterintuitive, at times bordering on unwise or even nonsensical, that it momentarily appears to reduce the solution space to a minimum. This in accord with Reitman's (1964) idea of 'discontinuous transitions in the problem space' (306), which is caused by the problem-solver violating his constraints at a given time. Further, Reitman notes that if a problem-solver does engage in violation of the constraints, (s)he then *'has no guarantee that progress on the new problem will have any relevance to the previous one'* (ibid.). Our interest is closely related to better understanding this violation of constraints, which involves significant risk taking. As Reitman (1964) explains: 'The greater the number and complexity of the violations … the more the problem solver risks introducing complications, interactions, or contradictions when he attempts to reconcile his latest work with the antecedent problem' (307). What we focus on here is not merely a trivial constraint violation (to use Reitman's term), but a radical one in the sense that a creative agent intentionally attempts to make his/her own creative challenge at hand seemingly insoluble by radically violating the constraints at hand by setting up new ones. Because a decision to engage in such a practice of radical self-binding is rooted entirely in an agent's free will and ingeniousness, decisive constraints adhere to the decision of applying a radical, self-imposed creativity constraint to stimulate the process. In other words, it is related to *radical decision-making*.

This leads us to formulate the first of two definitional conditions. According to *definitional condition 1*, for an act to be conceived as an application of a *decisive constraint* in a design process, the act must represent:

> *(1) A voluntarily and intentionally chosen obstruction in the form of one or more creativity constraint/s that diminish(es) the agent's*

> *solution space dramatically. This instalment of a radical self-imposed creativity constraint must to a very large extent go against the agent's own prior (tacit or explicit) knowledge from experience as well as the relevant design community's expectations to what are seen as standard and usual solution alternatives within the domain.*

Implementing such a highly limiting choice in the design process is important, but the crucial part is what follows from it. According to P.D. Stokes (2006), genuine breakthrough results may potentially be achieved by deliberate dichotomous thinking, i.e. by deliberately thinking in preclude–promote constraint pairs. Although she never mentions Elster's (2000) work, this idea bears close resemblance to his so-called essential constraints (see Figure 1), which are defined as constraints that an agent freely and intentionally imposes on (him)herself for the sake of some expected benefit to (him)herself. This expected benefit could very well be the attainment of something highly original and satisfactory—such as a work of breakthrough quality. According to Elster, applying self-imposed constraints forces the agent to be original because it provides a narrower frame in which to 'maximise aesthetic value'.

Establishing such a starting point bears some resemblance to Darke's (1979) concept of 'primary generators'. Darke presents the idea that to make a vast set of solution alternatives more cognitively manageable, designers 'fix on a particular objective or small group of objectives, usually strongly valued and self-imposed … These major aims, called here *primary generators*, then give rise to a proposed solution or conjecture' (43, emphasis in original). Darke's conceptualisation is in accord with our own proposed concept, decisive constraints; however, there is a key difference. For Darke, the primary generators in a given design process are conceptualised as 'objectives [that] form a starting point for the architect, a *way in* to the problem' (38, emphasis in original). In other words, Darke's concept specifically—and only—addresses the *initiation* of a design process. It is a way in to the problem and is not meant to be used continuously to accelerate an ongoing process. As will appear shortly with definitional condition 2, what our concept is aiming to capture does not adhere to the beginning of the process. It is an attempt to gain analytical insight into the relation between creativity constraints, radical decision-making and creative turning points *during* the design process.

Similarly, we would like to point out that our definitional condition 1, as presented above, is in alignment with McDonnell's (2011) work on *enabling constraints* as a form of imposition of order in creative processes in art and design. Informed by findings from filmmaking and design, McDonnell defines 'enabling constraints' as 'devices, arbitrary, pragmatic, aesthetic and other which artists or designers impose to create a discipline for the working process' (559). The enabling characteristic of voluntarily imposing various constraints on the creative process is generally in accord with our concept of decisive constraints; however (as outlined in Section 3.1), creativity constraints by definition encompass a duality by simultaneously enabling *and* restraining the solution alternatives. These two characteristics must be balanced for a design process to progress based on the imposition of creativity constraints. Another difference is the radicalness of the decision-making. McDonnell explains that she focuses on 'the relationships between the decisions that are made that can be construed as imposing enabling constraints, and the creative potential which is thus set in place once a regime is decided upon' (ibid.). Our present scope shares this focus; however, what we are aiming to capture is decision-making using creativity constraints that veer significantly from the norm, i.e. that distinctly oppose usual solution alternatives and professional expectations of the relevant (design) community. This is why we have introduced the distinction between *trivial* and *radical* self-imposed creativity constraints.

This radicalness as a key element our definitional condition 1 means that we also distinguish our concept from Elster's view on the severity of constraint intensity (or 'constrainedness'). Given his reluctance to embrace artistic contributions from

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certain avant-garde movements, it would seem very likely that the level of constraint pressure he would advocate with regard to 'maximising aesthetic value' is quite moderate. As opposed to a mere 'challenge' in this sense, what we wish to address with the decisive constraints concept does not refer to some abstract, normative goal or statements such as: 'I want to make the best calendar app graphical user interface (GUI) ever.' On the contrary; our notion of decisive constraints as outlined in definitional condition 1 specifically concerns very concrete rules, choices and voluntary acts of self-binding. As will become clear in Section 4, where we apply the two definitional conditions of our proposed concept to three media façade installation projects, reaching for decisive constraints as a processual resource may entail choosing odd, but very tangible, design materials, or clear formulations of highly restraining sets of guidelines or rules to govern the concerted creative efforts in the design process. Thus, when we employ the term 'dramatically' in definitional condition 1 to denote the intensity of the act of implementing one or more radical self-imposed creativity constraint(s), either during or at the outset of the design process, this level of constrainedness cannot be universally assessed. It relies on the agent's individual domain experience and (tacit and explicit) knowledge. The vital part as stated in definitional condition 1 is that the creative agent, the designer, pushes (him)herself to a point where there are no longer any immediate standard solutions at his/her disposal.

3.4.2 Definitional condition 2: creative turning points

As practitioners know, an ingenious creative choice in the design process may appear very provocative or almost nonsensical by being extremely challenging to the agent him/herself and/or the design team, but *without* leading to an innovative, final design. Phrased differently, the application of a radical self-imposed creativity constraint may indeed satisfy definitional condition 1, but nevertheless *not* yield any real progress or spur fruitful, new ideas resulting in a truly original final design. Indeed, radical self-imposed creativity constraints may lead to a *dead end* in the design process, or in Reitman's (1964) problem-solving terms, 'the solution set defined by the particular complex of constraints [. . . would appear] empty' (299). This raises the important definitional question as to whether decisions satisfying definitional condition 1 are decisive if they mark a turning point in the design process, but nonetheless lead to a dead end, not an innovative outcome. Also, it could be asked how many such failed decisive constraints there are compared to fruitful ones. Both are valid concerns, and they form the basis for definitional condition 2 below.

To refer back to the motivation behind this article, what we focus on here is the intriguing observation that highly limiting, creative decisions of voluntary self-restraint, i.e. the free imposition of radical creativity constraints, may *occasionally* accelerate the design process and lead to a highly original final design. It is the actual *productiveness* of this seemingly disadvantageous act that we aim to embrace and explore by introducing decisive constraints as a conceptual lever for gaining better insight into design processes, especially the nature of qualitative forward leaps or turning points. Since our interest lies in the productiveness or *resourcefulness* of radical self-imposed creativity constraints, a quantitative assessment of failed vs fruitful constraints is relevant, but beyond the scope of this article. This study only investigates the observation that voluntary application of radical creativity constraints seems to strongly affect the originality of the outcome of the design process. Given our present focus on the resourcefulness of applying various creativity constraints to a design process, we deliberately ignore such instances in which radical self-imposed creativity constraints lead to a dead end in the design process. By resorting to the imposition of such self-binding in expectance of a thus more original outcome, the designer obviously takes a chance, perhaps even gambles, due to the evident possibility of working toward a dead end. This means that the designer needs to muster courage to accompany his/her domain skills and (tacit and explicit) knowledge from experience if (s)he decides to engage in the imposition of radical self-imposed creativity constraints to leverage the design process at hand.

In our view, the importance of a designer's previous experience in this way does not undercut the general value of decisive constraints as a creative resource in the design process. Rather, it would seem that resorting to radical self-imposed creativity constraints could be of more value to an innovative, adventurous, expert designer than to a peer with less pronounced experience and domain savvy and thus a lesser need to challenge his/her own previous solution alternatives (see also P.D. Stokes [2006, 2007, 2009] on creative experts being more inclined to employ preclude-promote constraint pairs).

This elaboration on the productiveness or resourcefulness of decisive constraints, or more precisely their status as qualitative forward leaps or turning points *directly related* to the final outcome, is comprised in the second of our two definitional conditions. In our treatment of P.D. Stokes's proposed if–then conceptualisation of dichotomous, paired constraints leading to creative breakthrough (see Section 2.2.3), we stressed the importance of human intention and that this must be manifested (and thus be observable) in the form of concrete creative decision-making. With regard to design, this importance of human intention as a capacity for creative change in the physical world is emphasised by Nelson and Stolterman (2012, 38): 'It is a hallmark of design that human intention is essential and central to the instigation of change in the real world. Human intention is, therefore, a singularly important and consequential cause of change.' To address the intricate relation between intentional change and cause in the real world, Nelson and Stolterman coin the term 'design cause':

> *Design cause is the consequence of human volition and the capacity for humans to be proactive and purposeful in their interaction with the real world. Design cause is essential both for initiating change that brings new things into existence and for modifying those things that are already in existence* (38).

According to this definition, design cause is clearly identifiable as a theoretical construct related to an intentional 'push' toward greater concreteness and complexity in moving from idea to final design (the ultimate particular). It is the designer's intent to 'push' in terms of evoking design cause via decisive constraints that we wish to address. In practice, such as in a design process, proving direct (design) causality between an act of intentional change and a concrete design outcome, the ultimate particular, is a highly challenging task. The more controlled the research experiment (*in vitro*) in order to reduce the number of variables at play to demonstrate causality, the more detached from a real world design setting (*in vivo*) the experiment becomes.

Acknowledging the complexity and difficulty involved in showing causality in design in a convincingly manner, we believe that it may be beneficial to turn to jurisprudence to help establish the necessary criteria for our definitional condition 2, which targets the emergence of creative turning points following radical self-imposed creativity constraints. What we suggest is the legal standard of proof 'beyond a reasonable doubt'. This is:

> *The standard that must be met by the prosecution's evidence in a criminal prosecution: that no other logical explanation can be derived from the facts except that the defendant committed the crime, thereby overcoming the presumption that a person is innocent until proven guilty . . . The term connotes that* evidence establishes a particular point *to a moral certainty and that it is* beyond dispute *that any reasonable alternative is possible . . . Beyond a reasonable doubt is the highest standard of proof that must be met in any trial* (Farlex, *The Free Legal Dictionary*: 'beyond a reasonable doubt', emphasis added).

Although this crucial legal standard neither implies, nor establishes full transparent causality in an affirmative sense, it still articulates a certain point after which it becomes undisputable that other explanations may be possible. As this is deemed the highest standard of proof in any trial, we would argue that it suffices for our present purpose.

This legal standard enables us to formulate the second definitional condition. According to

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definitional condition 2, for a creativity constraint to be truly *decisive* in an intentional act of creative self-binding in the design process, it must also:

> *(2) Be related, beyond a reasonable doubt, to the final creative outcome of the design process in being of crucial importance to redefining the (new) solution space. Thus, for a creativity constraint to be 'decisive' in application, it must be conducive to creative performance and, in the form of a creative turning point in the process, lead to the attainment of an original, concrete solution (a final design), not merely a dead end.*

This second definitional condition addresses what happens in the design process once the radical creativity constraint has been (self-)imposed by the agent(s) involved. The creativity constraint must be decisive in the sense of being utmost critical (crucial) to the final result of the design process. Whether a constraint may be seen as decisive in this second meaning of the term (as formulated in definitional condition 2) can only be assessed after the fact (*a posteriori*). As with the term 'dramatically' in definitional condition 1, the standard 'beyond any reasonable doubt' in definitional condition 2 is hard to assess once and for all. Rather, it is meant to serve as a (moral) guideline (Farlex, *The Free Legal Dictionary*: Beyond a reasonable doubt'). What is important is that it may be rendered more than extremely probable, thereby invalidating all possible alternative explanations, that one or more of the final design's key characteristics (see Norman's [2002] affordances) can be traced back to the voluntary instalment of the (self-imposed) radical creativity constraint(s). We have elsewhere shown how such a tracking of ideas and design elements can be carried out in a concrete setting (Dalsgaard, Halskov, and Nielsen 2008).

To sum up, our deliberate use of the duality inherent in the term 'decisive' relates to both *radical decision-making* (see definitional condition 1) and to *creative consequence* in terms of the emergence of a creative turning point on the way toward an original final design (see definitional condition 2). This interpretation is in alignment with the etymology according to ordinary use of the term in English (Farlex, *The Free Dictionary*: 'decisive'). With the concept *decisive constraints* presented and defined by definitional conditions 1 and 2 (Section 3) on the backdrop of our review of main contributions to creativity constraint typology research (Section 2), we will now put our concept to the test. This means returning to practice, as we will apply our two definitional conditions to three media façade installation projects in which our interaction design research lab, CAVI, has recently been involved. Our core contribution, the introduction of the concept *decisive constraints* as an analytical tool, is intended to help gain better insight into the nature of dynamic project settings and how design processes evolve from initiation to conclusion. Our chosen domain is interaction design, and based on findings from the three case examples in Section 4, we broaden the scope in Section 5 by briefly considering how our concept may help inform current design theory. We argue that decisive constraints may also serve as an inspiring resource for practitioners not only in interaction design, but assumingly also in related creative domains and disciplines. Finally, in Section 6, we briefly offer a set of conclusions.

4 Cases

4.1 Media façade installation projects as exponents of decisive constraints

As implied in the term itself, interaction design puts emphasis on establishing and ensuring a resourceful space of action for its involved agents (Löwgren and Stolterman 2004). This space can be found in digital user interfaces in the private sphere, often embedded in various kinds of home or portable technology, or installed in the public domain, e.g. as large digital displays in an urban setting. Interactive media façade installations are an attractive medium for us as design researchers to work with, as it evokes a multitude of cognitive perspectives in the users' interactive encounter with the installations. As mentioned in Section 2.3.2, our participation in these interaction design projects has been planned and executed as

research-through-design. Partakers in these three particular projects include artists, architects, industry professionals, scholars, professional designers, computer scientists and others, so the sheer confluence of contributions from such a varied array of disciplines has helped us gain insight into some of the key dynamics of creativity constraints and how they are managed during a design process. Given that media façade installations can be conceived as digital artefacts, public interfaces, interactive spaces, items of ubiquitous computing and more, this conceptual complexity means that the process through which the installations come into being makes for a rich and suitable place to explore the complex dynamics of creativity constraints.

In recent years, we have directed an increasing amount of attention toward the design process itself in the form of development of tools, techniques and maps for the various stages of a project's progression; for instance, 3-D projection tools (Dalsgaard and Halskov 2011), the inspiration card workshops technique (Halskov and Dalsgaard 2006, 2007), and maps for design reflection (Dalsgaard, Halskov, and Nielsen 2008). It is this work we draw on in the following, where we put our concept decisive constraints to the test in order to show how the concept may contribute to inform the current understanding of design processes. By applying our definitional conditions 1 and 2 (see Sections 3.4.1 and 3.4.2) to the three media façade installation projects, we aim to show how our concept decisive constraints may offer new insight into some of the vital ways in which *creativity constraints*, *radical decision-making* and *creative turning points* not only converge in the design process, but converge in a unique manner that is conducive to reaching an innovative final design. We will discern key challenges in each project, but it is beyond the scope of the article to engage in a more comprehensive outline of the numerous creativity constraints that characterised each design project. The important part here is the use of decisive constraints as a conceptual lever to understand how and why the design projects evolved and ended as they did, and thereby also show our concept's relevance to creative practitioners, among them designers in particular. The three media façade installation projects were conducted between 2007 and 2010 and differ from each other in terms of process duration and process form, degree of creative freedom (or conversely, constrainedness) in the process, number of participants, use of digital technology and extent of in-situ interaction, as the research reported is located in an intersection between architecture, motion graphics and interaction technology. The first case concerns a proposal submitted to an architectural competition in 2007.

4.2 Warsaw's new art museum

The Danish architecture studio, BIG, was invited to present a proposal to the architectural competition for the design of a new museum of modern art in Warsaw, Poland, and our lab was brought into the process to help develop ideas and solutions for integrating interactive technology into the building's façade and interior surfaces. During the initial stage of the process, we assembled a large amount of material concerning the physical site and the surroundings of the proposed museum, and we conducted a study of technologies and materials that potentially could be applied in the design process. For the next step, we employed the inspiration card workshop technique devised by Halskov and Dalsgaard (2006). This is a collaborative approach to combining domain knowledge with technological sources of inspiration. Domain knowledge is represented by domain cards and may be generated by the participants from the design domain. Technology cards, primarily generated by the designers, represent technologies that may directly or indirectly be part of the design concepts. The main phase of the workshop consists of the participants collaboratively combining the cards on posters in order to capture various design concepts. As discussed by Dalsgaard, Halskov, and Nielsen (2008), one of the materials introduced in the workshop was *thermo-chromatic concrete* (TCC), invented by Royal College of Art design students Christopher Glaister, Afshin Mehin, and Tomas Rosén (see http://www.innovation.rca.ac.

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uk/718/all/1/Chronos-Chromos-Concrete.aspx), which utilises a current applied to a heating element embedded in the concrete to make the temperature rise, thereby causing it to change colour, an effect made possible by mixing a heat-sensitive ink into ordinary concrete. During the workshop, several other technologies were introduced and discussed as potential starting points for exploring ways of transforming the architecture into media architecture. With no obvious starting point at hand well into the workshop, the principal architect made the radical decision that TCC was the technology he wanted to use. Due to the unique properties of TCC, he intentionally chose to employ this specific material as a means to push the workshop forward and in a new direction, because he knew that the use of TCC would represent a severe limitation of the solution space, which he assumed would provoke the team to generate novel ideas and thus spur progression. Accordingly, the entire team immediately considered the radical decision to use TCC significantly more restraining than enabling due to its low resolution, slow refresh rate and limited colour scheme. As a radical self-imposed creativity constraint, choosing TCC went against the team's prior knowledge, experience and first choices in terms of preference for vanguard digital display technologies. This means that definitional condition 1 (see Section 3.4) for a constraint to be *decisive* is satisfied.

One of TCC's intrinsic constraints, i.e. unmalleable constraints given by the material and context (see Elster's [2000] constraint tripartition as presented in Section 2.2.4), is that its colour changes quite slowly: from just a few seconds to fifteen seconds when a section of the concrete is heating up, and even more slowly when it is cooling down. Another intrinsic constraint concerns using TCC to make a display with pixels. The original inventors of TCC made a video of how a single tile of TCC could change from grey to white, and in another example they showed how digital numbers of seven lines could be individually controlled (see Figure 2). Such a digital display was made by wiring individually controllable electrical heating elements cast in concrete.

During the initial part of the process, we pondered how to produce and control heat, e.g. by using tubes filled with hot water or incorporating electrically heated elements. One idea was to use TCC to make visible the consumption of energy in the building, e.g. making hot water consumption visible on the walls when people turned on the hot water in the bathrooms, or making visible the wiring of flex-tubes in floors as part of the underfloor heating system. We investigated in greater depth the idea of using TCC to make a low-resolution display composed of individual tiles organised in a matrix. As this use of TCC was technologically innovative, offering the stern constraints of a very limited colour scheme and low resolution, we conducted a series of experiments. First, we explored the appearance and perceptions of the varied imagery using the filters of a photo manipulation tool followed by an investigation of the potential appearance of a Vincent van Gogh self-portrait. We made several versions of the portrait, varying the opacity to get an impression of how it would look during the transition from low to high heat intensity (see Figure 3 below). One of the insights was the observation that the van Gogh self-portrait took on an unmistakable resemblance to Lenin, which, for historical reasons, we considered unsuitable for a Polish museum. So, we carried out similar experiments using Leonardo da Vinci's *Mona Lisa* portrait (see Figure 3) with studies of scale and perspective as pivotal factors affecting perception. Findings from these experiments were included in the final competition proposal, concluding the creative process.

In this design case, it seems evident that the principal architect's radical decision to use TCC and embrace all its intrinsic constraints, with which no one on the team had any experience, became the very turning point for the entire design process. Establishing this creative turning point in the process means satisfying definitional condition 2 (see Section 3.4) for asserting a creativity constraint's decisiveness, i.e. its relation, beyond a reasonable doubt, to the final outcome of the design process by way of indisputably redefining (delimiting) the solution space without leading to a dead end. What this first case example shows is

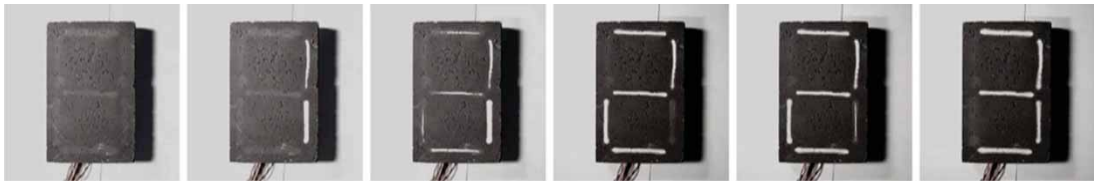

Figure 2. Thermo-chromatic concrete (TCC). Photo credit: Glaister, Mehin and Rosén.

not merely how intrinsic constraints, in this case notably material ones, can be managed constructively. More importantly, it demonstrates the creative resourcefulness of applying *decisive constraints* to an interaction design process in order to reach an original final design.

4.3 Aarhus by Light

As part of our interaction design research lab's ongoing exploration into media architecture (see Dalsgaard, Halskov, and Nielsen 2008; Brynskov et al. 2009; Dalsgaard and Halskov 2010; Korsgaard et al. 2012), we approached Musikhuset, the city concert hall in Aarhus, Denmark, to enquire into the possibility of temporarily integrating a media façade into the architecture of the building. The marketing director agreed to the idea and gave us quite unrestrained opportunities. Our technology partner, Martin Professional, who operates in the market for media architecture, offered to supply some of their LED panels for the installation. This was a kind and welcome offer; however, we were unsure how suitable these panels would be for the development of the concert hall media façade. Among the significant constraints intrinsic to the panels was the low resolution of the display, owing to the 40 mm distance between the individual pixels. Another severe, intrinsic constraint was the fact that the LED modules were only available in fixed dimensions of either 1×2 metres or 2×2 metres. The glass façade of Musikhuset is 700 m^2. We initially planned to cover the entire façade with LED panels, but Martin Professional imposed the additional (external) constraint that only 180 m^2 of LED panels would be available for the project. Although the opportunity to use the LED panels was much appreciated, we pondered different possible solutions to the design problem at hand. One reason for looking toward other materials was the limited availability of the LED panels. This was considered a huge step backward, since we were concerned that if we did not cover the entire façade, the result would simply look like a screen mounted on the façade rather than as an integrated part of the building.

As opposed to the vast freedom of the Warsaw case, this project was bound by at least three severe intrinsic constraints: the limited availability of the LED panels; the low resolution of the display; and the fact that the design had to fit an existing building. We in the design team had begun generating various ideas for the media façade project before we even met with Musikhuset's marketing director, so these three constraints posed a grave challenge to our musings. Despite being concerned that it could be hard to reach a satisfactory design, we accepted the offer and decided to embrace these severe material constraints in order to let them define the solution space, thereby dramatically narrowing down our creative options in terms of solution alternatives. As opposed to the Warsaw case, where the principal architect ultimately took the radical decision, in this Aarhus by Light case the determination to freely and intentionally restrain ourselves by welcoming these three radical creativity constraints was a joint decision. Thus, it is an example of radical decision-making, which means that definitional condition 1 for a creativity constraint to be decisive is satisfied.

Through many iterations and a sketching process, we managed to come up with a solution: organising the panels in a non-rectangular pattern to avoid a screen-like effect (see Figure 4).

One of the key intrinsic constraints adhering to the structure of the building was that the huge glass façade was organised into square and rectangular areas. Fortunately, the dimensions of most

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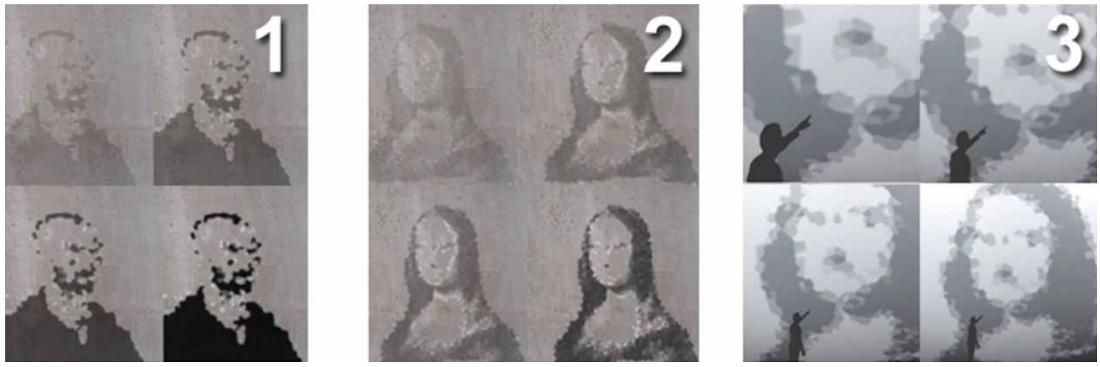

Figure 3. Three visual experiments into TCC.

of the squares matched those of the 2×2 metre LED panels, which eased the integration of the LED panels into the building's façade. The low resolution of the LED panels, though, offered the most critical constraint, as it had strong implications for the imagery displayable. Through a series of design workshops and experiments, our collective team decided on two principle graphical elements: a constantly moving outline of the Aarhus skyline, as well as a number of animated, Tamagotchi-inspired creatures (see Figure 5).

The visual style of both elements was deemed suitable for meeting the constraints presented by the resolution of the panels. An interactive element was combined with the city skyline and the animated creatures. Cameras were mounted at three locations along one of the main access paths through the park, and custom-designed software identified the outlines of people's bodies as they approached Musikhuset. The outline of a person's body was then transformed into a silhouette on the display (see Figure 6), which in this way became a self-imposed creativity constraint for us as designers and an imposed constraint for the citizens of Aarhus with regard to the kinds of possible interaction.

As discussed in detail by Brynskov et al. (2009), the silhouette encouraged a curious, playful investigation of the façade among the users while enabling them to interact with the creatures. By moving their silhouette back and forth and from side to side, the users were able to push, pull, lift and drop the creatures on the façade. Since the glass façade was organised into square and rectangular areas, these were utilised as a constraint-enabled feature by having the small creatures enter and exit virtual doors at the vertical edges of the rectangular areas, climb up and down the vertical edges and occasionally lay down to sleep on the horizontal edges.

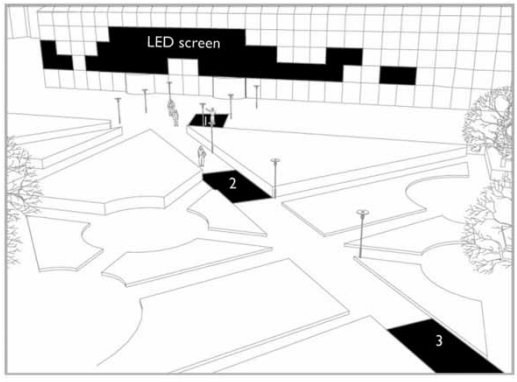

Figure 4. Configuration of LED models and interaction zones.

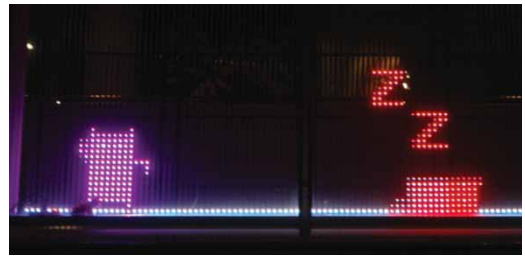

Figure 5. Graphical elements of Aarhus by Light.

As mentioned, we in the design team shared strong initial concerns as to how suitable the LED panels would be for a project design on which we were already working. At the time, the three main intrinsic constraints (as presented above) led us to think that if we wanted to go through with the project, we would have to run the risk of not reaching a satisfactory process outcome. On the other hand, being aware of this possibility of failure informed our decision to wholeheartedly embrace the panels as our main material for the design process. And this dismissal of a resort to standard or usual solution alternatives became crucial—or better, decisive—for the final design for Musikhuset. The ultimate design solution generated a substantial amount of attention and interaction in front of Musikhuset (see Brynskov et al. 2009), and can, specifically and beyond a reasonable doubt, be traced back to the radical decision-making of embracing the three highly limiting creativity constraints as presented above. Furthermore, as the team's acceptance of these constraints did not lead to a dead end, definitional condition 2 for decisive constraints is also met. Similar to the first example, the Warsaw art museum proposal, this second example illustrates the resourcefulness of radical, self-imposed creativity constraints in an interaction design process.

4.4 The Danish EXPO 2010 pavilion

The Danish pavilion at EXPO 2010 was designed by the Danish architectural firm, BIG. The interior of the helical building acted as a 300-metre-long exhibition area, and the outer façade of the pavilion was perforated with almost four thousand holes of various sizes and configurations. Due to the double-loop structure of the building, the façade was almost 300 metres long and from some angles appeared as two bands, one above the other. The layout of the holes reflected the statics of the building, meaning that the façade was a part of the load-bearing structure, and holes were present only where the statics and the inner construction allowed them to be placed. The original proposed idea suggested that the holes would simply be plain holes.

As opposed to both the extensive creative freedom of the Warsaw art museum proposal and the immediate need to completely revise our already burgeoning initial design ideas in the Aarhus by Light case, our interaction design research lab became involved in this project after the building design had already been determined. Entering the process quite late meant that we had to adjust not simply our initial ideas, but more importantly our design approach itself (research-through-design), according to which we as designers and researchers take part in all aspects of the design process right from the beginning.

Since we had previously collaborated with BIG in the field of media façades and with the lighting manufacturer, Martin Professional, the idea of turning the perforated façade into a media façade emerged quite naturally. In essence, our first thought was to design a media façade that would articulate the expressive pattern of the façade during the evening hours of the EXPO. The idea of illuminating the nearly four thousand holes embossed into the façade as opposed to working with significantly larger, two-dimensional surfaces presented a strong challenge calling for an innovative approach. Also, the fact that the surface was curved and the pixels' shape three dimensional (not two-dimensional 'dots') was not easily resolved. However, getting the opportunity to really challenge our tacit knowledge and try to come up with a completely new design in the middle of a process that we had not been involved in from the beginning was so tempting that we decided to take on the project.

Our basic idea was to add lighting fixtures to the cavity wall above each tube passing through the façade. The tube would therefore have to be made from a translucent material that would make each hole appear as an illuminated, tube-shaped pixel on a media wall. The scale of the building, its double-loop structure and pixel geometry of four thousand pixels distributed over a band almost 300 metres long, were all powerful, intrinsic constraints for the entire team. The design of the media façade evolved over a period of thirteen months through a series of design experiments and activities where we applied tools and employed

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Figure 6. Citizens interacting with Aarhus by Light.

models created during the development period in order to examine different properties of the façade and to visualise design ideas as they emerged (see Halskov and Ebsen 2013).

One of the initial experiments included testing light sources on a full-scale mock-up (see Figure 7). This served as a platform for testing light fixtures and the quality of the individual pixels with regard to colour and light intensity. One of the findings from these experiments was the observation that, due to the tube-shaped holes, the individual pixels would appear differently depending on the viewing angle, e.g. as a circle or a crescent. During the process, we knew that the irregular distribution of pixels forming a long low-resolution display was a critical intrinsic constraint offering particular challenges in terms of what content it would make sense to develop. In order to explore the perceptual possibilities of the façade pixel, we developed a software application capable of visualising a small section of 24 of the total 627 columns in the façade. The software tool was utilised to test a variety of forms of content, including video footage, animation, text and abstract graphics. One of the findings was the fact that horizontal lines were hard to perceive, and that text was only faintly perceivable.

Although the 300-metee-long, double-loop-structured pixel geometry in itself imposed serious limitations on the design process, we found it necessary to formulate a set of self-imposed creativity constraints to promote the originality of the eventual design solution. Concretely, this took the form of a *design manifesto* with seven elements to guide us in identifying our options in terms of solution alternatives:

1. *medium*: the facade lighting is not a screen, and should be regarded as a part of the architecture;
2. *architecture*: the lighting design should emphasise the architecture, and not constitute a visual takeover;
3. *form*: the visual expression should be created with sensitivity to the layout of lighting fixtures, and the pattern they form on the façade;
4. *speed*: all movements and changes in lighting must be slow;
5. *adaptive*: light levels will be adjusted according to measured sunlight levels;
6. *colours*: the overall colour scheme consists primarily of white or shades of grey, with some details in either black or red;
7. *visual content*: the visual content should build on already existing visual features of the pavilion.

Figure 7. Full-scale mock-up.

Resorting to a design manifesto in an attempt to promote originality was new to us and thus represented a breakaway from our typical design strategy. Essentially, it severely challenged our tacit design decisions by cutting off standard solutions and usual choices based on prior experience and knowledge, and it forced us to re-evaluate our domain savvy and toolkits as designers. Employing a rigid design manifesto of various creativity constraints in this way exemplifies radical decision-making, which thus satisfies definitional condition 1 for a self-imposed creativity constraint to be considered *decisive*.

In order to further probe what might constitute feasible content using the design manifesto as a set of self-imposed creativity constraints, we developed a virtual 3-D model. This enabled us to visualise content in a spatial configuration corresponding to the form of the building, hereby addressing especially the first two of the design manifesto's seven dogmas in the form of self-imposed creativity constraints. These first two were *medium* and *architecture*. In contrast to commercial visualisation tools available on the market, our own tool enabled us to also address item three of the manifesto (*form*) by visualising our lighting fixtures as tubes. Our final visualisation tool was a 1:100 scale model of the building on which we could project a virtual 3-D model of the configuration of holes as they would be illuminated on the pavilion. Such a mixed reality approach enabled us to map visual content onto the configuration of the holes in the virtual model and view the result on the physical scale model (see Figure 8).

The various tools described were used in a series of workshops involving approximately fifty design experiments, leading to a collection of content designs such as walking and bicycling silhouettes of people, Chinese characters and black-to-white gradients moving around the building. The various content designs were produced within the frame set by dogma four, six and seven of the manifesto (*speed*, *colours* and *visual content*) and evaluated up against the very same set of self-imposed creativity constraints. Owing to the constraints presented by the scale and shape of the building as reflected in dogma one to three of the manifesto, the final decisions and adjustments were conducted on-site in Shanghai.

Given the sheer complexity of this particular project, the path toward the final design featured

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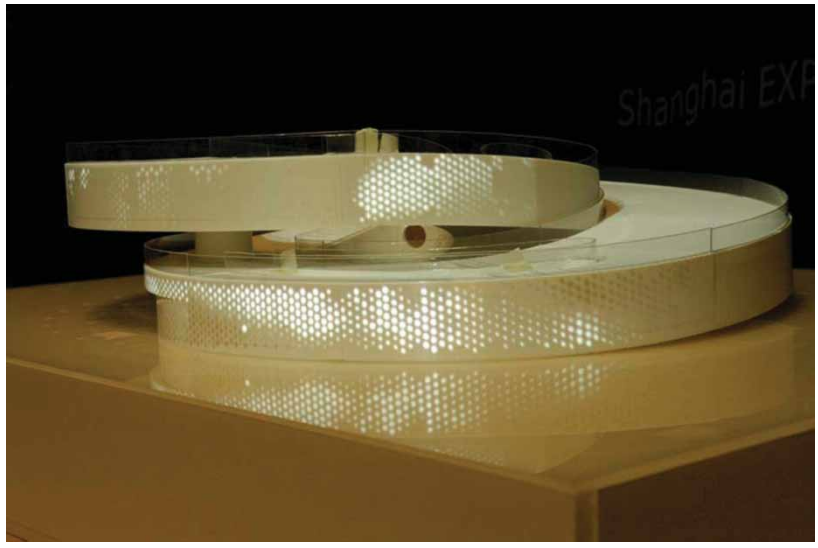

Figure 8. Mixed reality model.

numerous technological constraints, both intrinsic ones and many imposed by partners. The careful formulation of a seven-point design manifesto with specific guidelines to inform the last part of the design process bore a direct and apparent impact on the final design, not least because it was used iteratively as a cross-reference (in the evaluation) to make sure that the team did not deviate from the course represented by the aesthetic values and preferences of the manifesto. Thus, with regard to *decisiveness*, definitional condition 2, requiring relation, i.e. legibility beyond a reasonable doubt, between radical, voluntary decision-making and the attainment of the final design goal is met in this case example as well. While the Warsaw art museum proposal and Aarhus by Light were mostly based on material choices, the Danish EXPO 2010 pavilion exemplifies a somewhat more abstract choice of self-restraint in relying on a severely restraining set of values that required

Figure 9. The Danish EXPO 2010 pavilion. Photo credit: Leif Orkelbog.

interpretation from the team. Although these three interaction design cases differ in many ways, their shared scope as media façade installation projects notwithstanding, they all show the creative potency of voluntary pre-commitment or even self-binding in a design process. It was this particular design strategy, based on radical decision-making in the articulation and implementation of what we with this article suggest be labelled *decisive constraints*, including custom development of appropriate tools and models, that made it possible for us to present an original final design for the Danish EXPO 2010 pavilion as illustrated in Figure 9.

5 Discussion

5.1 Theoretical and practical relevance of decisive constraints

The employment of self-imposed creativity constraints in a design process is common among practitioners; however, we believe this phenomenon must be lifted out of the anecdotes and studied more carefully in order to become of use to even more creative professionals, not just in design, but potentially in related creative domains and disciplines as well. A quick search entry of 'decisive constraint' on Google Scholar yields approximately 330 hits (as of August 2013). Still, the concept and how it affects the design process and its outcome in terms of differentiating between *levels of importance among constraints* from ideation to final design has not been sufficiently analysed or explored. Many researchers address constraints in their work, and examples include the aforementioned problem-solving analyses by Reitman (1964, 1965) and Simon (1996, 1973), Stefik's (1981) work on hierarchical planning as constraint posting in computer science (AI) and, more recently, Fischer's (2004) research into socio-technical environments for design communities (he uses the term 'barriers' in lieu of constraints) and Coughlan and Johnson's (2007, 2008) quartered typology related to end user development, which is based on Pearce and Wiggins's (2002) work on constraints in musical composition. Although these and other studies concern constraint management, the scope of these analyses specifically concerns how intrinsic and externally imposed constraints, to use Elster's acute tripartition (see Section 2.2.4), affect a process in one domain. This means that the term 'constraint' is utilised to distinguish between various levels of obstacles and requirements in a particular process in a particular domain.

We propose a slightly different approach that puts strong emphasis on conceptual consistency without sacrificing relevance to creative practitioners. In offering two minimal definitional preconditions for determining whether a self-imposed creativity constraint should be considered *trivial* or *radical*, possibly even *decisive* (see definitional conditions 1 and 2 in Section 3.4), we concur with D.R. Stokes's (2006) idea of a minimal ontology. As shown in the previous literature overview of research into constraints pertaining to creative processes, what appear to be consensually applied terms tend to conceal discrepancies, inconsistencies and conceptual cloudiness that hamper immediate progression of theory. What one discipline calls 'practical constraints' another denotes as 'task constraints', while a third uses the terms 'material' and 'technical constraints.' Even when the scope is generic based on philosophical analyses to address the issue, such as in Elster's (2000) work, daydreaming is presented as an example of creativity with no constraints (181). Against this we would argue that time available for this activity is always a delimiting factor and that daydreaming is context-dependent by being affected by noise and ambience from the milieu, and is always framed as erotic, exotic, humorous, surreal, etc. based on the agent's decided, or unintended, set of preferences and cognitive abilities. This exemplifies how the terminological opacity and vast array of specialised mono-disciplinary conceptualisations of constraints render it hard to formulate a unifying typology to cut across creativity-related disciplines. Our contribution, the formulation of decisive constraints based on exploratory studies and design research projects in interaction design, marks only a small step toward a more refined and cohesive understanding of creativity constraints as an integral part of design processes. This raises the question as to

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whether decisive constraints as an analytical concept may have relevance for other creative domains and disciplines as well.

5.2 Decisive constraints as a creative resource in a broader perspective

The expression 'decisive constraint' came up in passing in a chat with two close colleagues, Onarheim and Wiltschnig, in Denmark, and although it was never probed analytically, we could all immediately relate to the concept with regard to previous design research projects in which we had been involved. This observation supported our shared conviction that self-imposed creativity constraints should be qualified and discussed more critically than has been done so far. Our previous (Biskjaer, Dalsgaard, and Halskov 2010; Biskjaer, Onarheim, and Wiltschnig 2011) and ongoing studies of design, in particular interaction design, and artistic processes substantiate the observed resourcefulness and importance that innovative voluntary self-restraint can yield in a creative activity. In an art-oriented perspective, examples of this include the Danish *Dogma 95 Manifesto* (the 'Vow of Chastity') for filmmaking, according to which the director must steer clear of usual and standard artistic choices, idioms and preferences and instead subject (him)herself to a number of severe demands such as no artificial lighting, only hand-held camera, only Academy 35 mm film, etc. Another example of such artistic self-binding is Icelandic singer Björk, who chose to make the album *Medúlla* (2004) with extremely few instruments, using almost solely layered vocals and *a capella* singing. A third example is American artist Matthew Barney, who, from 1987 to 1989, created the first series, *Drawing Restraint 1–6*, of an on-going acclaimed art project in which he explores how self-inflicted encumbrance stimulates creativity much like the way forced resistance such as lifting weights helps build muscle tissue for an athlete. In his first series, Barney takes a radical approach, as he struggles to paint while being physically restrained via cords and karabiners in his studio. As briefly mentioned, the literary avant-garde experiments of the French Oulipo group from 1960, including the heavy use of formal genre constraints such as lipograms and palindromes by novelists like George Perec and Italo Calvino and others (Symes 1999; Andrews 2003; Mathews and Brotchie 2005) comprise many intriguing examples to be explored more in depth by means of key insights into creativity constraints in addition to literary studies (see also Onarheim and Biskjaer 2013). Based on preliminary musings on these four and other examples, we have a strong hunch that our concept 'decisive constraints' can be relevant not only to help improve the understanding of the creative processes that lead to the final artefact, but also to explore to what extent and how decisive constraints are employed as a rich creative resource in artistic processes. Although it is too early to conclude anything, our preliminary findings suggest an evident resemblance to design processes as presented in this article.

As the title of the article indicates, our focal point is the *resourcefulness* that may stem from an agent's voluntary and intentional imposition of creativity constraints on (him)herself. This invites the question whether undertaking self-imposed creativity constraints, in particular radical ones, is always necessarily beneficial. Are there no costs or drawbacks? Certainly, this is a valid concern, which deserves a more thorough treatment than what falls within the specific scope of this article. Any successful creative endeavour brings with it the risk of the creative agent, be it a designer, an artist, an entrepreneur, etc., becoming undermined by his/her own success. The same holds true for the creative outcome, for instance an artefact, which can lose value and merit on a number of levels (aesthetic, financial, etc.) and suffer the fate of eventually becoming obsolete, clichéd or even worthless. French Impressionist Claude Monet (1840–1926) chose water lilies in his garden in Giverny as his main motif during the last thirty years of his life. It is assumed that his water lilies series comprises around 250 paintings of this single motif. While Monet's artistic influence can hardly be overestimated, lesser creative minds would no doubt have run a great risk of

undercutting their originality and potentially reducing their works to clichés had they sustained such a remarkably narrow and uncompromising idiom in their career, including continuously adhering to more or less the same set of self-imposed creativity constraints. Also, as pointed out by P.D. Stokes (2009, 174), creative practitioners are often rewarded for their reliability, and this is another reason why unaltered self-imposed creativity constraints may indeed become dull, and stereotypical, thereby eradicating the very originality they were intended to promote. To break out of this situation, the creative agent must invent a new set of self-imposed creativity constraints that may again serve as a resource and potentially become decisive in his/her creative processes.

In addition, it should be noted that constraints *proliferate* (Reitman 1964). Each new creative choice entails new creativity constraints, and the more radical they are, the more severely they cut off paths to potential solutions that may be better than what is compatible with the new self-imposed creativity constraints. As mentioned, there is no guarantee that such self-binding may be reconcilable with the original problem, in this case a design brief (see Section 3.4.1). Like all creative processes, it is by no means certain that the outcome following from an application of self-imposed creativity constraints, let alone decisive constraints, is good or successful in terms of how well the end product, be it an artefact or a design, is eventually received by the market, critics, users, etc. On a more speculative note, the reasons for such an undesirable outcome could possibly be found in aesthetic or cost-related inadequacies or exaggerations (among others), and there is no doubt that decisive constraints may be utilised in a non-productive way. Similarly, working with too few creativity constraints may lead to the same adverse effect: an unsuccessful final design. Both are valid concerns; however, addressing these complex issues more in depth lies beyond the scope of this article, as our interest is explicitly the resourcefulness of decisive constraints.

The aim of our core contribution, the proposed concept ‘decisive constraints’, has been to show how this theoretical construct may be useful to help inform an improved understanding of design processes by offering insights into some of the ways in which *creativity constraints*, *radical and adventurous decision-making* and *creative turning points* converge in the design process in a unique way that is conducive to reaching a truly innovative final design solution. It is in this regard that we argue for the resourcefulness of decisive creativity constraints with relevance to practitioners as well. This, however, gives rise to a critical question: why does the array of individually tailored, mono-disciplinary conceptual models and terminology not suffice? Why not simply ‘play it by ear’, i.e. rely on ad hoc solutions and dissemination of domain-specific concepts and terms as needed among the design team members and other partakers in the project? Concurring with observations by Mamykina, Candy, and Edmonds (2002), we have experienced the need to quickly agree on a transparent language with concise concepts in our interaction design research projects. A main reason for this is the fact that these projects have included many creative professionals trained in diverse disciplines, but all forced to engage in creative collaboration on the fly. We hold the conviction that much research into creativity constraints in design and beyond contains unexplored exciting insights still confined by imprecise conceptualisations and fettered by lack of definitions. Such insights represent a rich resource just waiting to be unfurled. Our emphasis on creativity constraints as being of major importance to not only future design research, but creativity research as such, is echoed by Kaufman and Sternberg, whose closing chapter in the most recent edition of the seminal *The Cambridge Handbook of Creativity* (2010) specifically links new avenues of thought in creativity research to a refined understanding of constraints (Sternberg and Kaufman 2010).

Obvious next steps in terms of research will be to further explore constraints as a resource in creative processes in related disciplines and areas of research, not least the arts, including the performing and the plastic arts, analogue and digital media and individual and collaborative processes. A key

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point of interest will be a more in-depth analysis of the delimitation of self-imposed creativity constraints in general and decisive constraints in particular. Another topic to be studied in more depth is constraint management as balancing constraints (see also Onarheim 2012b). As our present scope is *exploratory* and *descriptive* with the limitations that this approach entails (Dalsgaard, Halskov, and Nielsen 2008; Dalsgaard and Halskov 2012), the critical question to inform such future studies is a *prescriptive* (normative) one: *how to do it well*, meaning concrete strategies for use of creativity constraints as a means to elevate creative performance and spur progression in order to attain originality in the final outcome, not only in design, but potentially in various creative practices. Onarheim (2012a) has taking steps in that direction in a study of engineering design, and together we are currently building on previous observations of expert handling of creativity constraints (Biskjaer, Onarheim, and Wiltschnig 2011) in an investigation of how to establish the 'right' amount of constrainedness by manipulating fixed creativity constraints (inherent and imposed) or, conversely, by freely adding extra ones (self-imposed) to enter a so-called 'sweet spot' of creativity as a malleable (design) space where the agent(s) feel(s) most productive (Onarheim and Biskjaer forthcoming).

As the art examples above suggest, the *process* of artistic creation, as opposed to the artefact and its appropriation, is yet to be probed more comprehensively by scholars working within philosophy of aesthetics (a notable exception is the work by Gaut and Livingston [2003]). Currently, there is not even an established paradigm for a philosophy of creativity, although the interest in the topic is growing (see D.R. Stokes 2006, 2008; Gaut 2010, 2012; Klausen 2010). Scholars from other disciplines, from Schön's (1983, 1987) seminal studies of creative professionals to recent contributions from management science (Austen 2010) have contributed to this field, and the findings' relevance to the more art-oriented milieus in the humanities seems clear, albeit still little explored. Finally, we would like to note that also neuroscientific research seems an exciting new area for future research into creativity constraints. While some creativity constraints are malleable insofar as they can be challenged and modified (e.g. imposed technical constraints in interaction design), some are not, as they are always already embedded and present in the creative agent's faculties. How these two types of creativity constraints converge and affect each other is an interesting topic that calls for more research (see also Onarheim and Friis-Olivarius 2013).

6 Conclusions

In this article, we have shown how our proposed analytical concept 'decisive constraints' can serve to inform an improved understanding of design processes. As a theoretical contribution, our concept has been formulated to help gain better insight into some of the crucial ways in which *creativity constraints*, *radical decision-making* and *creative turning points* converge in the design process in a unique way that may lead to dead ends, but, more importantly, may also be a path toward a genuinely original final design solution. Our point of departure for case-grounding our analytical concept in order to show relevance for design practice has been interaction design as our primary domain, here instanced as three cases of interaction design experiments that have led to examples of innovative media architecture. The three case examples illustrate the complex correlativity of creativity constraints in a design process, and the intricate dynamic interplay between timeframes, materials, levels of usability and interaction, costs, etc. as examples of creativity constraints seems a promising topic for coming studies. Informed by lessons from these cases, a first conjecture would be to probe key concepts such as context and content to help analyse, conceptualise and concretise opportunities for promoting creative originality or excellence as these emerge in the design process.

To ensure conceptual consistency, analytical relevance and practical applicability, we have built decisive constraints on two preconditions, definitional conditions 1 (related to radical decision-making) and 2 (related to creative turning points). Informed by a review of key

contributions to previous and current constraint research, this has entailed a new reading of Darke's (1979) concept 'primary generator', as we argue that there may be more than one, and that such particularly important (decisive) self-imposed creativity constraints grounded in radical decision-making are integral to shaping the solution space and evolve in response to dynamic project settings. Also, our proposed conceptualisation enables a new interpretation of Nelson and Stolterman's (2012, 31) theory of design as a process of 'moving from the universal, general, and particular to the ultimate particular – the specific design'. In this view, introducing decisive constraints in a given design process may be seen as an intentional 'push' toward greater concreteness and complexity in the transition from idea to final design. As much as we would like to explore our proposed concept's potential relevance for other aspects of design theory, including a thorough discussion of and reflection on its limitations, it is beyond the scope of this article to investigate the potential of decisive constraints when applied to some of the main design paradigms such as applied arts, engineering, human-centred design, user-centred design and, very recently, Balanced, Integrative and Generous (BIG) design (Cockton 2012), among others. However, with our proposal of 'decisive constraints' as an analytical concept to help gain new insights into decision-making and turning points in design processes, and as a concrete means for practitioners to embrace creativity constraints as an inspiring resource, our intention has been to make the path toward these and related creative endeavours more accessible.

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