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Less is sometimes more – constraint-based design principles for creativity support systems

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Received 29 July 2024
Revised 3 February 2025
27 May 2025
Accepted 22 June 2025

Abstract

Purpose – The study investigates how limitations within creativity support systems (CSS) can enhance virtual team collaboration and creativity. Recognizing the challenge of technological overload due to CSS's increasing features and functionalities, the research aims to show how strategic constraints can foster rather than hinder creative processes.

Design/methodology/approach – Adopting a design science research (DSR) methodology, this study synthesizes kernel theories and insights from expert interviews to develop 11 meta-requirements and five design principles for constraint-based CSS. These principles were then tested through a series of real-world experiments to evaluate their effectiveness and refine them based on empirical results.

Findings – The findings reveal that implementing constraints in CSS can significantly boost radical creativity, adaptation and activity in virtual teams. It also helps reduce cognitive overload, feature fatigue and topic drift, thereby enhancing the efficiency of creative collaboration across different phases. Each design principle was empirically validated and refined, underscoring the benefits of constraint-based approaches in managing feature-rich environments.

Originality/value – This research contributes to the understanding of how constraints can be systematically designed and applied in CSS to promote creativity. By empirically testing and refining design principles for constraint implementation, the study offers a novel perspective on balancing functionality and simplicity to optimize creative collaboration in virtual settings.

Keywords Collaboration, Computer-supported collaborative work (CSCW), Design science, Creativity management, Information system analysis and design, Group support system (GSS)

Paper type Research article

1. Introduction

To adapt to shorter product life cycles and new requirements for products and services at an accelerating pace, organizations need to enable teams to collaborate creatively and develop radical ideas that differ substantially from existing products, services, practices, frameworks, or processes (Acar *et al*., 2019; Agarwal and Karahanna, 2000). The development of new information and communication technologies (ICT), among other factors, has given rise to virtual teams in which globally distributed members address complex problems and transform novel solutions into innovative market-ready products or services (Anning-Dorson, 2018; Cascio and Montealegre, 2016; Pacauskas and Rajala, 2017). According to Dulebohn and Hoch (2017, p. 569), virtual teams are "work arrangements where team members are geographically dispersed, have limited face-to-face contact, and work interdependently through electronic communication media to achieve common goals". As this requires the digitization of previously analog work practices for creative collaboration, new creativity support systems (CSS) are being developed that offer various means for communication,

Information Technology & People
Vol. 38 No. 8, 2025
pp. 140-171
Emerald Publishing Limited
e-ISSN: 1758-5813
p-ISSN: 0959-3845
DOI 10.1108/ITP-07-2024-0949

information exchange, and collaborative creativity (Dulebohn and Hoch, 2017; Fiol and O'Connor, 2005; Gabriel *et al*., 2016; Müller-Wienbergen *et al*., 2011; Thatcher and Brown, 2010; Voigt *et al*., 2013). CSS are information systems (IS) that are specifically designed to support creativity-intensive processes (Shneiderman, 2007) and consist of humans, tasks, and technologies (Heinrich *et al*., 2011). CSS aim to enable virtual teams and individuals to innovate and come up with novel and appropriate responses to the challenges they face (Frich *et al*., 2018; Gabriel *et al*., 2016; Müller-Wienbergen *et al*., 2011; Pacauskas and Rajala, 2017; Voigt *et al*., 2013).

It seems logical that more features help mitigate more limitations of virtual collaboration and benefit the autonomy and creativity of collaborators. Therefore, they should yield better outcomes. As CSS providers aim for competitive advantages and differentiation, the number of digital systems used to support creativity and collaboration, as well as the number of features and functionalities has continued to grow over the past years (Adam *et al*., 2017; Chandra *et al*., 2019), involving a wide range of capabilities for interaction, knowledge sharing or innovative collaboration processes (Becerra *et al*., 2021; Chao *et al*., 2020; Dulebohn and Hoch, 2017).

However, research finds that the complexity of features and information in CSS can cognitively strain users, require extensive learning, and make it more difficult for them to concentrate on essential and relevant tasks (Chandra *et al*., 2019; Siemon *et al*., 2017; Tarafdar *et al*., 2007; Voigt *et al*., 2013). This can cause effects such as technostress (Chandra *et al*., 2019), cognitive load (Rodet, 2022) or feature fatigue, and a desire for systems that are more basic and have fewer functionalities (Fu *et al*., 2020; Thompson *et al*., 2005). Previous studies suggest that interventions like blocked or limited availability of tools or interactions, referred to as constraints, during certain phases of creative collaboration, can help teams access the instrumental potential of a CSS more efficiently, or benefit idea generation and exploration beyond routine performance (Biskjaer *et al*., 2019; Coughlan and Johnson, 2008; Pilcicki *et al*., 2022; Wu and Bryan-Kinns, 2019).

The extensive literature presenting theories, concepts, and design knowledge of CSS has grown steadily over the past decades (Frich *et al*., 2018). Research on CSS has a long tradition in IS, leading to a wide variety of frameworks, guidelines, design principles (DPs), features and functionalities that have been developed (Carraher Wolverton *et al*., 2022; Müller-Wienbergen *et al*., 2011; Resnick *et al*., 2005; Shneiderman, 2007; Voigt *et al*., 2013) to investigate the mechanisms and effects of CSS on individual and collaborative creativity.

Despite previous research on creativity under constraints (Acar *et al*., 2019; Caniëls and Rietzschel, 2015; Onarheim and Biskjaer, 2015; Tromp and Sternberg, 2022), and the availability of prescriptive design knowledge on how to design features and functions in CSS, the body of design knowledge on CSS does not sufficiently address constraint-based strategies to mitigate the negative effects of feature abundance and foster creative collaboration based on empirically validated, prescriptive knowledge that specifies the underlying mechanisms of constraints for the design and implementation of constraints into CSS. This is particularly important as the need for collaborative creativity and innovation in virtual teams continues to increase (Dulebohn and Hoch, 2017; Madjar *et al*., 2011) while users experience higher levels of fatigue due to features, information, and social overload (Chandra *et al*., 2019; Fu *et al*., 2020; Thompson *et al*., 2005). Against this background, our research investigates the following research question:

RQ. How can constraints in CSS be designed to support creative collaboration?

To answer our research question, we follow the design science research (DSR) paradigm (Akoka *et al*., 2023; Hevner *et al*., 2004). We synthesize concepts and theories of collaborative creativity (i.e. kernel theories, KTs) such as feature fatigue, cognitive load, and social facilitation. On that basis, we explore how expert facilitators and creativity coaches use constraints (implicit and explicit) in CSS to foster creativity in teams, based on twelve semi-structured interviews. We then derive user stories based on the results of the expert interviews and create meta-requirements (MR) in synthesis with the KTs. We further synthesise the MRs and construct five DPs, which we then operationalise to evaluate each DP in an experimental setting (i.e. workshops). Based on the results, we further refine the DPs and present a final, evaluated version of our DPs, with which we contribute empirical knowledge to the topic of creativity under constraints in the context of virtual collaboration, as well as practical knowledge on how constraints can be implemented in CSS. We illustrate how constraints in CSS can stimulate more radical forms of creativity beyond routine performance, encourage adaptation and activity in CSS, and enable expression and exploration for inexperienced users.

2. Theoretical background

2.1 Systems that support creativity

The performance of creativity-intensive tasks can be supported by ICTs that are designed and deployed to enable groups and individuals (Carraher Wolverton *et al*., 2022; Forgionne and Newman, 2007; Gabriel *et al*., 2016; Pacauskas and Rajala, 2017). These so-called CSS are sociotechnical systems that enable users to facilitate and document processes to support creativity (Voigt *et al*., 2013). Cognitive and social stimulation of participants is fostered through information sharing, idea comparison, and synchronous communication in CSS (Müller-Wienbergen *et al*., 2011; Voigt *et al*., 2013).

Numerous research articles examine the design and application of various features and functions in CSS and their effects on creativity (MacCrimmon and Wagner, 1994; Massetti, 1996; Müller-Wienbergen *et al*., 2011; Shneiderman, 2007; Voigt *et al*., 2013). Studies have illustrated how functionalities and digital mechanisms can stimulate and impair group creativity processes and collaborative dynamics (Siemon *et al*., 2017; Voigt *et al*., 2013).

Creative collaboration is complex and often involves various processes and activities (Kaptelinin and Nardi, 2012b), and CSS need to represent this complexity in their design (Seidel *et al*., 2010; Wang and Nickerson, 2017). According to media richness theory, high information breadth and depth for information exchange and communication in CSS benefit collaboration in virtual teams (Daft and Lengel, 1986). In line with this idea, the importance of open, simple interchange and rich communication has been stressed repeatedly (Shneiderman, 2007, 2009), alongside a variety of other features (Voigt *et al*., 2013).

However, when collaborators find themselves unable to cope with technological overload and complexity and face adaptation problems, technostress can occur (Chandra *et al*., 2019; Tarafdar *et al*., 2007). Increased workloads and accelerated learning efforts (Tarafdar *et al*., 2007) due to feature abundance can exhaust users, increase their cognitive load, and interfere with their ability to concentrate on essential and relevant tasks (Fu *et al*., 2020; Pacauskas and Rajala, 2017; Thompson *et al*., 2005). Cognitive load can make collaborators shift from thoughtful contemplation to less deliberative processing (Allred *et al*., 2016), significantly reducing the quantity and variety of creative ideas. To better support creative collaboration, CSS need to target cognitive processes and obstacles like these more deliberately (Chao *et al*., 2020; Elsbach and Hargadon, 2006; Gebbing *et al*., 2022; Rodet, 2022; Yu *et al*., 2022). Previous research finds that means of communication and interaction do not need to be available throughout the entire process, especially when collaborating creatively in rapid feedback cycles (Madjar *et al*., 2011; Pilcicki *et al*., 2022). For instance, collaboration can benefit from limited synchronicity and concurrency of media and communication in certain work phases, as the demands for idea generation differ from those of idea evaluation, for instance (Dennis *et al*., 2008; Gebbing *et al*., 2022; Schmidt, 2010). At the same time, moderate levels of stress can stimulate performance and challenge individuals in beneficial ways. Techno-overload and -complexity, for instance, have been found to have a curvilinear influence on IS-enabled employee innovation (Chandra *et al*., 2019; Galluch *et al*., 2015). Constraints, when too restrictive, can hinder creativity by reducing autonomy and cognitive flexibility, while too much openness and complexity can lead to cognitive overload, diminishing creative capacity (Acar *et al*., 2019; Onarheim and Biskjaer, 2015). This curvilinear relationship implies that an optimal level of constraint can stimulate creativity by structuring cognitive processes and directing problem-solving efforts in productive ways. However, existing studies have primarily focused on broad IS-enabled innovation rather than on CSS specifically, leaving open the question of how constraints should be designed to optimize creativity in CSS.

CSS can be designed to enable and motivate collaborators, for instance by providing specific triggers or blocking activities in a creative process (Biskjaer *et al.*, 2019; Gebbing *et al.*, 2022; Neate *et al.*, 2019). Behavior and decision-making in digital environments can be supported by a variety of constraint-based design interventions such as the reduction, tunnelling, and tailoring of tasks and information to user activity (Fogg, 2009; Forgionne and Newman, 2007; Lembcke *et al.*, 2019; Oinas-Kukkonen and Harjumaa, 2009; Weinmann *et al.*, 2016). However, there are no specific guidelines on how to design and implement constraints in CSS, and empirical studies that further explore their underlying mechanisms have yet to be conducted.

2.2 Creativity under constraints

Creativity under constraints involves generating novel and useful ideas within the bounds of explicit or tacit factors that govern what an individual or group can or cannot do, and what their creative output can or cannot be (Amabile and Pratt, 2016; Onarheim and Biskjaer, 2013). In the context of collaborative processes, constraints can be classified as input constraints (e.g. unavailability of resources or tools), process constraints (e.g. restrictions and process steps), or output constraints (e.g. factors that define the results of a process) (Acar *et al.*, 2019). These constraints can be inherent to tools or collaborative contexts, or they can be externally or self-imposed (Elster, 2000; Onarheim and Biskjaer, 2013). In addition, certain types of constraints, such as time limitations and feature restrictions, have been shown to be particularly effective to foster radical creativity. Radical creativity, which emphasizes transformative and exploratory ideation, benefits from structured boundaries that challenge routine thinking and promote divergent solutions (Madjar *et al.*, 2011; Onarheim and Wiltschnig, 2010).

Creative collaboration can focus on two types of creativity: ideas that differ substantially from existing practices and suggest new frameworks or processes, which are defined as radical creativity, or minor modifications to existing practices or products, defined as incremental creativity (Madjar *et al.*, 2011).

Within a creative process, work phases can be characterised as being driven by high openness (“divergence”) and work phases of careful analysis and synthesis (“convergence”) (Guilford, 1967; Runco and Acar, 2012). Contemporary creativity frameworks such as design thinking employ divergent and convergent work phases in an iterative manner to analyse problems and generate innovative solutions (Lindberg *et al.*, 2011). Researchers have pointed out that CSS need to distinguish and address the specific characteristics of divergent and convergent work phases more deliberately to best support creative collaboration along these phases (Gabriel *et al.*, 2016), and a deeper understanding of the mechanisms and effects of constraints in CSS bears tremendous potential to support these efforts.

Reason suggests that to support creative collaboration, constraints should be reduced because they limit employee autonomy, control, motivation, and creativity (Amabile *et al.*, 2005; Amabile and Pratt, 2016; Shalley *et al.*, 2004). However, other research suggests a curvilinear relationship between creativity and constraints and suggest a certain level of “constrainedness” as a prerequisite to creativity, which can be turned into creative outcomes by a variety of mechanisms (Acar *et al.*, 2019; Onarheim and Biskjaer, 2015). Constraints can enhance creative performance by directing cognitive focus, limiting excessive freedom, and fostering structured problem-solving approaches (Byron *et al.*, 2010; Roskes, 2015). Previous studies demonstrate that constraints can be applied to foster creativity to benefit both, divergent and convergent work phases (Biskjaer *et al.*, 2019; Onarheim and Wiltschnig, 2010; Pilcicki *et al.*, 2022).

Research found that in this process, constraints can be designed to limit or channel cognitive resources (Roskes, 2015), reduce task complexity and the need for information processing (Branscombe and Cohen, 1991; Simon, 1955), stimulate activation and engagement in creative activities and mitigate cognitive obstacles to idea generation (Butler and Roberto, 2018), for instance by introducing time pressure (Baer and Oldham, 2006; Schmitt *et al*., 2015). Constraints can be designed to induce activation or excitement via multitasking, causing residual activation to have a positive spill-over effect on creativity after people move from multitasking behaviour to a subsequent task (De Dreu and Weingart, 2003; Kapadia and Melwani, 2021). Byron *et al*. (2010) suggest that constraint-based strategies can significantly impact the relationship between stressors and creativity, and enhance creativity.

This corresponds with activity theory, which proposes that collaboration via CSS emerges based on the arising and resolving of tensions and instabilities within CSS during activities (Allen *et al*., 2016; Carroll, 2003; Kaptelinin and Nardi, 2012a, b). According to activity theory, collaborators divide tasks and adapt to tools or functionalities of a CSS in the course of collaboration (Kaptelinin and Nardi, 2012a, b; Wiser *et al*., 2019). This involves mediating instruments, participants, social context, rules for behaviour, overarching objectives, and division of labour (Kaptelinin and Nardi, 2012b). While these are promising findings, most studies on creativity under constraints did not have a specific focus on the support of virtual teams or have not been conducted in virtual settings. While it seems plausible that similar effects should apply to the context of virtual collaboration to certain degrees, this has yet to be empirically validated. Specific knowledge as to how to design and implement these constraints into CSS is still limited, and empirical studies looking further into these dynamics have yet to be conducted. In addition, while these findings highlight the mechanisms through which constraints influence creativity, prior research has not systematically examined how constraints should be implemented within CSS to effectively balance structure and flexibility. Most studies have focused on general creativity research or traditional work environments, rather than virtual collaboration and the specific technological design of CSS. Consequently, there remains a need for empirical research that explores how constraints can be deliberately embedded in CSS to optimize both creative ideation and execution in virtual settings.

2.3 Justificatory knowledge

Within our research context, we reviewed extant literature for justificatory knowledge (JK) and identified three KTs according to Möller *et al*. (2022), which will guide the development of our DPs and serve as reference points in the following section: KT1) Media richness theory, providing an established basis for the design of CSS in general, yet lacking empirical insight into when and how to constrain information sharing and communication to prevent overload, fatigue, and other negative side effects during creative collaboration. KT2) Activity theory, as a robust framework to study creative collaboration via CSS yet providing little insight into how constraints in CSS can be designed to stimulate tensions that benefit creative activity. KT3) Research on creativity under constraints, which offers insight into the potentials of constraints in creative processes but has yet to expand this knowledge from analogue settings into the context of creative collaboration in virtual teams. To contextualize the identified KTs for the purpose of this study, related JK (theories and concepts) was analysed for supporting knowledge on the KTs' underlying mechanisms and potential side effects in the context of creative collaboration via CSS (Table 1).

3. Research approach and methods

The design science research (DSR) approach is followed as proposed by Hevner *et al*. (2004), in order to acquire design knowledge about the design of constraints in CSS that effectively use constraints. The overall goal of DSR projects is to generate rigorously derived and relevant

Table 1. Identified kernel theories (KT) and justificatory knowledge (JK)

	Kernel theory	Justificatory knowledge	Key concepts	Sources
KT1	Media Richness Theory	JK1) Persuasion and Nudging JK2) Feature Fatigue and Stress JK3) Cognitive Load	Breadth and depth of information sharing; Decision- and behavior change; Technological overload and fatigue; Attentional capture	Schmidt (2010), Chao *et al.* (2020), Tarafdar *et al.* (2007), Weinmann *et al.* (2016), Oinas-Kukkonen and Harjumaa (2009), Fogg (2009), Thompson *et al.* (2005)
KT2	Activity Theory	JK4) Social Loafing JK5) Production Blocking JK6) Social Facilitation JK7) Psychological Safety JK8) Shared Understanding	Tension and instability; Interference and presence; Fear of negative consequences; Implicit coordination; Shared understanding	Kaptelinin and Nardi (2012b), Karau and Williams (1993), Nijstad *et al.* (2003), Amabile *et al.* (1990), Kahn (1990), Johnson *et al.* (2007), Redlich *et al.* (2018)
KT3	Creativity under Constraints	JK9) Theory of Creativity JK10) Radical Creativity JK11) Activation Theory JK12) Subsequent Creativity	Cognitive and social coping; Novelty and conformity; Divergent and Convergent thinking; Induction of activity; Multitasking	Stokes (2009), Acar *et al.* (2019), Chandra *et al.* (2019), Runco and Acar (2012), Madjar *et al.* (2011), Baer and Oldham (2006), Kapadia and Melwani (2021)

Source(s): Authors' own work

design knowledge (Hevner, 2007). DSR aims to create prescriptive knowledge that contributes to both the theory and practice of solving real-world problems to create innovation (Akoka *et al.*, 2023; Hevner, 2021).

In our DSR project, we generate design knowledge in the form of DPs as a formalized and abstract form of knowledge that addresses a class of problems rather than a single problem (Gregor *et al.*, 2020; Iivari, 2015; Purao *et al.*, 2020). DPs contain prescriptive knowledge, which represents a means-end relationship and indicates how an artifact should be designed to achieve a desired effect or aim. According to Gregor *et al.* (2020), DPs refer to "know-how", i.e. knowledge about how something should be designed to achieve the desired effect. In their article "Anatomy of a Design Principle", they refer to this component as means of achieving an aim. Further, we follow Möller *et al.* (2020) who propose two different processes for constructing DPs: (1) the supportive approach, in which generalizable design knowledge is created first, which is then concretized, and (2) the reflective approach in which concrete design knowledge (e.g. design features or instantiations) is created first, which is then abstracted and generalized. We follow the process in which DPs are "the provision of design knowledge up front to support the design of an artifact before the design process takes place" (p. 214), i.e. the supportive approach similar to "strategy I" as defined by Iivari (2015). Consequently, we first construct the DPs (step 1) and then evaluate them (step 2). We use a mapping diagram as proposed by Möller *et al.* (2020) to visualize the construction of our DPs and the synthesis of our captured empirical insights and to visualize how these insights are transferred to our DPs (see Figure 2). The construction of our DPs (step 1) consists of four major steps and includes the underlying JK (KTs and complementary theories) (Gregor and Jones, 2007; Möller *et al.*, 2022) that we identified (see theoretical background) and the results of a series of expert interviews that we conducted. This knowledge is then synthesized into our MRs (i.e. a MR refers to a requirement that addresses a general class of artifacts rather than a single instance) which subsequently serve as a basis for the construction of our DPs. We construct and formulate our DPs according to Gregor *et al.* (2020) in order to ensure that the

DPs are "understandable and useful in real-world design contexts" (p. 2). The full mapping diagram that helps to understand the construction and synthesis can be found in the appendix (Figure 3). After the DP construction, we evaluated the DPs (step 2) in a series of four workshop settings, in which each setting implemented one DP allowing an isolated examination (except DP 4 and 5 which were considered together). This procedure allowed us to empirically evaluate the prescriptive means-end relationship of each DP in isolation, i.e. examine whether the means to achieve the desired effect was achieved and whether the DPs are relevant. In the last step, we refine and adjust the DPs based on the results. Figure 1 shows our DSR approach and the methods that we applied during our reflective strategy of DP construction and evaluation.

3.1 Step 1: design principle construction

To gather empirical evidence about current practices and applications of CSS in creativity-intensive processes, we interviewed twelve experts who regularly facilitate digital creativity workshops and sessions and who choose and use CSS. The selection of the experts was based on three basic criteria: the experts should either lead or facilitate creativity workshops in practice, have a minimum of 4 years of experience in this field and conduct digital workshops in which they can co-design (i.e. select and adjust) the functions and features of the tools used. We recruited overall twelve experts who collectively have over 75 years of expertise and have conducted hundreds of creativity workshops across various organizational and collaborative settings.

The interviews were conducted using a semi-structured guideline including 16 questions (see Appendix Table A3) with the aim of investigating which constraints facilitators and creativity coaches use (implicit and explicit) to foster creativity in teams. The interviews,

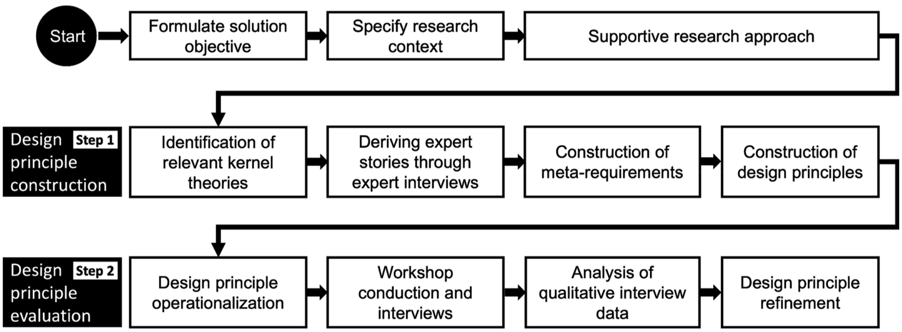

Figure 1. DSR process according to Möller *et al*. (2020). Source: Authors' own work

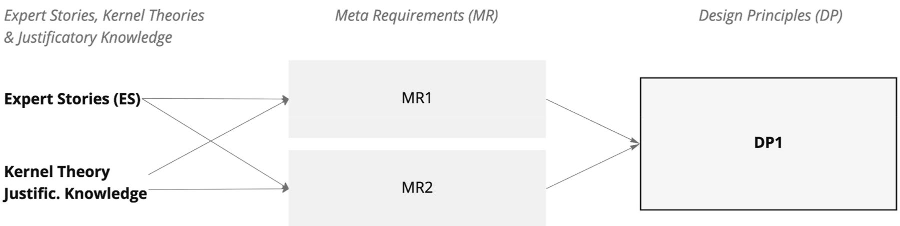

Figure 2. MR and DP construction scheme as mapping diagram (full version in Appendix Figure A1). Source: Authors' own work

which took place between June and September of 2021, lasted an average of 29 min. An overview of the expert panel including their work experience and job description can be found in Table 2.

The audio recordings of the interviews were transcribed and coded by two authors using MaxQDA in several iterative steps, analysing, refining, and extending the codes (Baur and Blasius, 2014). A combination of inductive and deductive coding was followed in which behavioural schemes and phenomena were identified inductively and utilized constraints were allocated to them deductively. We observed data saturation during the interview analysis, as no new themes or insights emerged after coding the data. Many aspects of the mechanisms behind constraints were mentioned repeatedly across interviews, reinforcing the validity and consistency of the findings. This process resulted in 70 codes reflecting four basic categories. This qualitative content analysis was then used to derive expert stories (ES).

Based on the uncovered codes of our qualitative study, ES were generated to comprehensively reflect the statements of the experts (Möller *et al.*, 2020). Summarizing the experts' statements in a generalized and synthesized form, these ES serve as the basis for the construction of MRs (Möller *et al.*, 2020). Table 3 shows an excerpt of the 32 generated ES including their corresponding category.

Our underlying JKs are reflected in the ES derived from our qualitative study. We aggregated the most common and repetitive ESs into four constraint categories as synthesized from the literature on constraints and creativity: process, collaboration, feedback, and features (Acar *et al.*, 2019; Gebbing *et al.*, 2022; Rosso, 2014; Wiser *et al.*, 2019). The category "process" sums up requirements and interventions affecting collaborators' activities and steps to be followed throughout a creativity process. The category "collaboration" sums up requirements and interventions affecting coordination and the distribution of work among

Table 2. Expert panel for the qualitative study

ID	Gender	Age	Profile
EX1	M	41	Innovation consultant, Media and Public sector, 9 years of experience
EX2	M	32	Innovation consultant, over 5 years of experience as a facilitator
EX3	F	32	Design Thinking coach, global IT agency over 5 years of experience
EX4	M	40	Innovation consultant, Media and Public sector, 7 years of experience
EX5	M	33	Innovation Manager, Automotive, 4 years of experience as a facilitator
EX6	F	37	Innovation Consultant, 8 years of relevant experience
EX7	F	44	Design Thinking Coach, IT sector, 12 years of experience as facilitator
EX8	F	33	Innovation Manager, Automotive, 4 years of experience
EX9	M	32	Design Researcher, 5 years of experience as a facilitator
EX10	M	36	Design Thinking coach, Media and IT, 8 years of experience
EX11	M	39	Innovation Coach, European IT firm, 12 years of experience
EX12	M	34	Agile Coach, Media, 4 years of experience

Source(s): Authors' own work

Table 3. Derived expert stories (ES) from qualitative study (scheme)

Category	#	Expert story (ES)
Process	ES1	*I want to make collaborators perform a second task parallel to their main activity*
Collaboration	ES11	*I want to block monologues and limit speaking time for collaborators*
Feedback	ES17	*I want to create an environment that does not follow collaborators' daily routines*
. . .	. . .	*I want to . . .*

Source(s): Authors' own work

collaborators. The category "feedback" sums up requirements and interventions affecting communication and decision-making in their collaboration. The category "features" sums up requirements and interventions affecting the availability of media or functionalities within a CSS (Acar *et al*., 2019; Rosso, 2014; Thatcher and Brown, 2010). A complete version of the derived ES can be found in the Appendix (Table A1).

By synthesizing KTs, JK, and ESs, we derived eleven MRs and five DPs for constraints in CSS, using the guidelines proposed by Gregor *et al*. (2020). We provide further details on the MRs and DPs in the following sections. Figure 2 illustrates our process of MR and DP construction as a schematic mapping diagram (Möller *et al*., 2020).

3.1.1 DP1: principle of Stimulation and Pause. According to the interview data, routine responses to external expectations can be a frequent obstacle to creative collaboration via CSS (i.e. copying existing solutions to new problems that would require further investigation). As multitasking can induce activation and creativity beyond routine performance (JK12 and JK10), experts requested adequate options for multitasking in the CSS (ES1). Since this can increase the cognitive load for collaborators' attention (JK3), the option to stop all activity in the CSS (ES2) was requested to support regeneration, but also stimulate spill-over effects from subsequent creativity (*"I use breaks to guide the creativity in a group"*, EX10) (*MR1*). To prevent distractions and overload (JK3), experts further requested the ability to intervene for focus, efficiency, and quality (ES7 and ES5) (*"I also want people to focus and not play around too much"*, EX11). As time pressure can promote creative activity when combined with continuous support (JK11), abilities to limit and visualize time for work phases were requested (ES3 and ES4), as well as an option to celebrate achievements (ES6) (*MR2*). During divergent process phases, the presence of co-workers can inhibit risk-taking and promote conformity or routine responses (JK10). As related stress (JK9) or lack of psychological safety (JK7) can inhibit creativity and engagement, experts requested options to block any form of negative feedback or discussions (ES17; ES18; ES19) (*MR3*). The resulting three MRs were used as the basis for DP1 (Principle of Stimulation and Pause).

3.1.2 DP2: principle of Blocking and Proceeding. According to our findings, a lack of focus and productivity can cause substantial challenges in creative collaboration via CSS. In order to prevent cognitive overload (JK3) while promoting efficiency and quality, experts requested the CSS to enable them to intervene in the collaborative process (ES5 and ES7) and enforce proceeding without questioning of results (ES8) (*"If something is important, it will pop up again later"*, EX1; *"You don't achieve breakthroughs with the classical settings. If you want radical ideas, more radical systems are needed"*, EX9). In order to promote creative activity via time pressure without the risk of decreasing motivation (JK11), adequate options to vary and visualize time limits (ES3 and ES4) and celebrate achievements were requested (MR2). Additionally, options to limit collaborators' overview of process steps and work areas aim (ES9) to prevent distraction and overload (JK3) (MR3). As creative activity in a CSS arises from tensions and instabilities in the system (KT2), experts further requested options to interrupt habitual activities and prevent distraction or overload (JK3 and KT2) by limiting the collaborator's means for communication (ES12), mutual interference (JK5) or blocking functionalities (ES13) on collaborators' computers (*"I want to prevent priming, for instance by using Google"*, EX10) (MR5). As individual efforts can decline in settings of collective activity (JK6), experts requested the CSS to enable them to intensify the presence of others in order to enhance activity (JK7) by making collaborators work in sub-groups and by making their activities visible or hide them (ES15 and ES16), depending on the work phase and collaborative dynamics ("It is much more difficult to hide if everybody sees your cursor", EX2) (MR6). The resulting four MRs were used as the basis for DP2 (Principle of Blocking and Proceeding).

3.1.3 DP3: principle of mixing and integrating. Successful collaboration requires collective activity based on a shared understanding of situations, tasks, and responsibilities (JK8). This can be a challenge for larger groups with a high degree of diversity, as our interviewees pointed out. To prevent fear of negative consequences, evaluation and interference by others in the process, and promote psychological safety (JK7), experts requested to be able to block monologues (ES11) and limit the means for interpersonal exchange (ES10), depending on familiarity of collaborators (ES13) (MR4). Decision-making as an activity of convergent thinking (JK9) arises from tensions in the CSS (KT2). As stress does not affect convergent thinking (Runco and Acar, 2012), experts requested to be able to intensify this process and stimulate tensions by mixing up collaborators differently (ES23). To support transparency and the productive resolution of tensions, the CSS was asked to enforce the mitigation and integration of objections (ES22) (MR8). The resulting two MRs were used as the basis for DP3 (Principle of Mixing and Integrating).

3.1.4 DP4: principle of initial limitation. In order to support creative collaboration in groups with limited experience or low levels of engagement, CSS should enable and motivate collaborators, while providing specific triggers that effectively support collaborators' decision-making and behaviour throughout the collaborative process (JK1). However, as CSS can inhibit creativity by overloading collaborators with technological complexity and capabilities beyond the required level (JK2), features and functionalities should be limited in order to decrease the need for information processing, channel cognitive resources, and prevent easy-to-generate ideas (KT3). A distinction needs to be made between the requirements for early and later-stage divergent thinking (JK9), as the breadth and depth of available media can be more or less well suited for prototyping and testing of ideas and hence needs to be adjusted to the collaborative context (KT1). Hence, experts suggest limiting options and features for creative expression (ES24 and ES25), note taking, and information sharing (ES26) in early-stage divergent thinking (*"I want the thoughts to be wide and the tool to be narrow"*, EX2) (MR9). To enable collaborators to use the system without special knowledge (ES29) and inspire adaptation and activity, experts want to offer work areas that are prefilled (ES30). In addition to that, the need was expressed to account for the requirements of different roles and skill levels (ES27 and ES28) (MR10). The resulting two MRs were used as the basis for DP4 (Principle of Initial Limitation).

3.1.5 DP5: principle of late variety. While media breadth and depth should be kept to a viable minimum in early-stage divergent creativity (MR10), experts requested large feature diversity and media richness for later-stage divergent creativity (ES32) for groups with limited experience or low levels of engagement ("I don't want people to drift into daily business, it has to be colorful", EX2). This way, collaborators are to be enabled and stimulated to explore, simulate, and prototype selected ideas (JK9; JK1; KT2), based on the requirements of different roles and skill levels (ES27 and ES28) (*"I don't want collaborators to panic because we are thinking differently"*, EX10) (MR11). The resulting three MRs were used as the basis for DP5 (Principle of Late Variety).

3.1.6 Initial design principles (pre-test version). The initial five DPs were formulated according to the anatomy of a design principle as defined by Gregor *et al*. (2020), specifying the context (actors, instances, or boundary conditions), mechanisms, and enactors (such as activities, processes or the manipulation of components or entire artifacts) and the rationale (as theoretically and empirically justified) for each DP. As an example, Table 4 shows the initial version of DP1 (for a complete overview of the initial versions of DPs 1–5, see Table A2 in the Appendix).

As the adjusted versions of our DPs based on empirical evaluation are presented later in this paper, Table 5 summarizes the key mechanisms and rationale of each DP pre-test.

3.2 Step 2: evaluation of design principles

The goal of evaluating DPs is to examine the prescriptive statement, i.e. the "means to achieve aim" (Gregor *et al*., 2020), and consequently to examine DPs for their effectiveness. In doing so, we primarily refer to the DP's effectiveness as proposed by Iivari (2015) (Iivari, 2015) and not to the extent to which the DP can be implemented by potential implementers or users, as also affirmed, for example, by Purao *et al*. (2020). Rather, we examine the dimension

Table 4. Example for the derived DPs (pre-test). DP1 formulated according Gregor *et al*. (2020)

	DP 1 stimulation and pause
Context Actor, instance, boundary condition	To spark radical forms of creativity beyond routine performance during divergent phases in the context of virtual collaboration
Mechanism (M) and Enactor (E) Activity, process, manipulation of other components/artifacts	M1) Employ sub-tasks that collaborators need to perform parallel to their main activities, M2) Enable the system to block activities at points of decreasing focus or after limited time periods, E1) Involve task repetition and celebrations of contributions
Rationale (R) Theoretical/empirical justification	R1) To stimulate positive spill-over effects between explicit and implicit conscious processes, R2) To prevent routine responses by collaborators

Source(s): Authors' own work

Table 5. Overview of the generated DPs 1–5 pre-test

	Context and key mechanism	Rationale
DP 1	Use of sub-tasks and activity blocking to spark radical forms of creativity beyond routine performance during divergent phases	Stimulation of spill-over effects, prevention of routine responses
DP 2	Use of blocked applications and proceeding process stages to promote focused activity and efficiency	Prevention of distractions, promotion of engagement
DP 3	Use of subgroups and limited interactions, to promote shared understanding and applicability of generated solutions during later stage convergent phases	Prevention of topic drift, promotion of psychological safety
DP 4	Use of subgroups and limited functionalities during initial stages of divergent thinking to enable inexperienced users to engage	Promotion of social facilitation and contributions
DP 5	Use of increased feature variety only during later phases of divergent creativity to enable inexperienced users to express, simulate and differentiate ideas	Prevention of cognitive overload, promotion of focus

Source(s): Authors' own work

effectiveness, i.e. the coherence of the prescriptive statement as proposed by Iivari (2015). In order to examine the prescriptive knowledge of each DP, we operationalized all DPs independently and, according to the relevant contextual conditions of each DP, evaluated them in a series of real-world workshops.

3.2.1 Sample data and procedure. The DPs were applied in the context of four separate, virtual, and creativity-intensive workshops with real-world teams working on distinct design challenges. Virtual teams rely on electronic communication to collaborate across geographic distances (Dulebohn and Hoch, 2017). The teams in this study align with this characterization, as they operated remotely using CSS to address complex challenges, reflecting the distributed and technology-mediated nature of virtual teams.

The selection of the teams followed four criteria: each team worked on a real design challenge requiring the collaborative generation of new ideas or solutions, teams fulfilled the contextual boundary conditions specified by the respective DP, team members had a minimum of two years of experience working together (with the exception of teams evaluated for DP4 and DP5, which targeted low-experience collaborators), and all teams engaged in creativity-intensive, collaborative processes. In total, 19 participants were involved in the evaluation across four workshops. An overview of the participants, teams and their characteristics is provided in Table 6.

Table 6. Overview of the workshop participants

Design principle	Industry	Age	Sex	Education	Organisation (yrs)	Team (yrs)	Role
DP 1	Media	32	m	Master	7	3	Team Lead
		38	m	Master	13	4	Team Lead
		28	m	Bachelor	5	3	Team Lead
		43	f	Bachelor	13	4	Unit Lead
		55	m	Master	22	4	Unit Lead
DP 2	Media	31	m	Bachelor	5	5	Team Member
		29	f	Master	6	2	Team Lead
		28	m	Diploma	4	4	Team Member
		27	f	Bachelor	2	2	Team Member
DP 3	Media	39	f	Diploma	12	7	Team Member
		30	f	Diploma	11	5	Team Member
		59	f	High School	40	6	Team Lead
		24	f	Maturity	5	2	Team Member
		27	f	Bachelor	7	7	Team Member
DP 4/5	IT	28	m	Master	0.5	0.5	Team Member
		25	m	Master	3	3	Team Member
		26	m	Master	2	2	Innovation Manager
		29	m	PhD	0.5	0.5	Innovation Manager
		27	m	Master	0.25	0.25	Team Member

Source(s): Authors' own work

The experiments took place between February and April 2022 and lasted 90 min each. Each team used a virtual whiteboard (Miro [1]) and a live video conference tool (Microsoft Teams) under the constraint conditions as specified by its DP. Before the experiment, participants were briefed to disable or close all other software and communication applications and devices, and to work in a closed room without co-workers, in order to minimize distractions. During the experiment, each team had to work on their design challenge in four steps, according to Lindberg *et al*. (2011): 1) Exploration (exploration of challenges, identification of relevant aspects and factors), 2) Selection (selection of relevant questions and aspects to be explored), 3) Ideation (generation of ideas and solutions, quantity without judgement), 4) Evaluation (analysis of results, selection of high potential solutions). Since DP4 and DP5 apply independent mechanisms to separate work phases, but both aim to support teams with high levels of inexperience, they were both applied to one workshop setting in sequence.

3.2.2 Measures and data collection. The evaluation of the DPs was conducted using asynchronous interviews with the workshop participants. A qualitative questionnaire was developed to specifically evaluate the means-end relationship of each DP. A qualitative approach was deliberately used because there was no manipulation (i.e. a control group) and because of the isolated observation of the DPs by independent workshops, the number of test persons was too small, so that a quantitative approach could not achieve meaningful results. Therefore, qualitative data collection was chosen, using established constructs to measure the means-end relationship. Similar to Vogelsang *et al*. (2013), these were transformed into individual questions asked in the post-workshop interview. Each asynchronous interview took around 5–10 min to complete. Data was then transcribed and independently coded by two authors following Mayring and Fenzl (2014). First-order and second-order codes were created by first deductively allocating codes to the desired end-goals of each DP as specified by its theoretical rationale, then secondly inductively deriving implications for further refinement of (sub-)components, activities or processes as specified by each DPs mechanism and context. Data saturation was reached during the analysis process, as no new themes or insights emerged after coding the data from all four workshops (Rahimi and Khatooni, 2024). It is important to note that the goal of evaluating the DPs was to examine the prescriptive statements—i.e. the "means to achieve aim" (Gregor *et al*., 2020)—and to assess the effectiveness of the DPs, as defined by Iivari (2015). This approach focuses on the coherence of the prescriptive statements rather than on the extent to which the DPs can be implemented by potential implementers or users. Given this analysis strategy, the deductive coding played a more prominent role, allowing us to identify and confirm key patterns efficiently. As a result, data saturation was reached fairly quickly, indicating that the sample size of 19 participants across four workshops was adequate for the study's objectives.

3.2.3 Operationalization of the DPs and interview questions.

DP 1 (Design Challenge: *"Creative news planning under stress and deadlines"*)

Working in prepared work areas, collaborators were given a set of subtasks to their main task during divergent work phases: 1) a creative subtask (adding free associations to others' contributions while posting own ones during exploration), 2) an analytical subtask (clustering results during group discussion during exploration), and 3) an interpersonal subtask (celebrating other's ideas during ideation phase) (Kapadia and Melwani, 2021). Between work phases, participants were asked to stop all activities and communications on the whiteboard and conference for a break of approximately three minutes.

After the experiment, participants were asked to report on their levels of immersion and focus (*"How absorbed were you in what you were doing and didn't let anything else distract you?"*, based on Cherry and Latulipe (2014) (Cherry and Latulipe, 2014)), radical creativity (*"To what extent do the resulting solutions show completely new ways that you have never tried before?"*, based on Madjar *et al*. (2011) (Madjar *et al*., 2011)), stimulation and subsequent creativity (*"To what extent did you suddenly come up with new ideas that you didn't even think of?"*, based on Kapadia and Melwani (2021) (Kapadia and Melwani, 2021)) and (*"How relaxed or stimulated did you feel?"*, based on Kapadia and Melwani (2021) (Kapadia and Melwani, 2021)) during the experiment.

DP 2 (Design Challenge: *"Collaboration and shared leadership between departments"*)

Collaborators worked in prepared areas which remained hidden until the group reached the according work phase. The time available for each work phase was limited and visualized for all participants throughout the experiment, no chat was allowed to prevent distractions. At the end of each time period, collaborators were asked to stop all activities and move on to the next work area, starting another timer, until all four work phases were finished. After the experiment, participants were asked to report on their levels of focus and distractedness (*"How concentrated or distracted were you during the exercise?"* based on Agarwal and Karahanna (2000) (Agarwal and Karahanna, 2000) and Cherry and Latulipe (2014) (Cherry and Latulipe, 2014)), collaborative efficiency (*"How efficiently did you work together and concentrated on the essentials?"*, based on He *et al*. (2007)) and engagement and topic drift within the group (*"To what extent was everyone involved without getting bogged down in unnecessary discussions?"*, based on Gilson *et al*. (2005)) during the experiment.

DP 3 (Design Challenge: *"Workplace design after the pandemic"*)

After a collective exploration phase within the main group, participants were divided into two subgroups at the end of the selection phase. Focusing on two separate aspects of the design challenge, subgroups worked in separate video calls during the ideation phase and were merged again for the final evaluation phase. The main group then was guided through a three-step process with limited speaking time per person and disabled group chat, systematically addressing clarifying questions, relevant objections, and integration of feedback into the final ideas. After the experiment, participants were asked to report on the levels of shared understanding within their group (*"How well did you understand your topic together?"*, based on Johnson *et al*. (2007)), applicability of ideas (*"How feasible are the ideas you found?"*, based on Madjar *et al*. (2011)), psychological safety (*"How comfortable did you feel sharing* *thoughts and ideas with others?"*, based on Kahn (1990)) and topic drift (*"How much did you stay on topic without losing focus?"*, based on Runco and Acar (2012)) during the experiment.

DP 4 and DP 5 (Design Challenge: *"Marketing synergies between two projects"*)

As DP 4 and DP 5 are conceptually related and require the same conditions within a group (i.e. low levels of experience) while focusing on separate phases in the creative process (initial and later divergence), an experiment was set up to isolate and evaluate the means-end relationships of both DPs within one group. During the exploration and selection phases (initial divergence and initial convergence), participants were not allowed to use colour-coding and sticky notes except the most basic type within simple work areas, with simple examples given for their application. For the following ideation and evaluation phases (later divergence and later convergence), restrictions on features were removed and participants were allowed to use any media or elements available within a prepared work area. For DP 4, after the experiment, participants were asked to report on the levels of ease of use and early engagement (*"How well did you find your way around the app and were you able to work right from the start?"*, based on Venkatesh *et al*. (2003)), without hesitancy to contribute (*"How easy was it for you to share your ideas with others and thus make a valuable contribution?"*, based on Bogost (2010)), Social Facilitation (*"How did it motivate you to work with others and see how everyone contributes?"*, based on Amabile *et al*. (1990)) during the experiment. For DP 5, after the experiment, participants were asked to report on their levels of focused exploration, cognitive overload (both based on Cherry and Latulipe (2014)) and creative self-expression (*"How good were you at experimenting creatively and exploring different ideas and possibilities?"*, based on Cherry and Latulipe (2014) during the experiment.

3.3 Results and discussion of the evaluation

We summarize the results in Table 7 by using different symbols (+, −) to indicate the level of support for the proposed means-end relationship, i.e. the effects that result from the design choice of the DPs. We used ++ or −− symbols to show strong support for the specific proposition that focused on the increase or reduction of an effect. For propositions that were generally supported, we used a simple + or − symbol. Using these symbols helped us to summarize the level of support for each means-end relation of a DP in a clear and easy-to-understand way. We discuss the results in detail after we presented the overview.

3.3.1 Observations and findings for DP1 (principle of stimulation and pause). Participants reported mixed levels of distractedness due to external demands and leadership responsibilities via phone and email (*"I can't completely forget my everyday work because it's still beeping and ringing everywhere"*) during the experiment. After approximately 60 min, a substantial decline in focus and activity could be observed within the group (*"I found it very hectic as time went on, because the arrows of my colleagues were constantly buzzing around")*, leaving only two of five collaborators active in the CSS. Nevertheless, participants found that within the 90 min, they were able to generate radical ideas beyond routine performance (e.g.: *"We came up with ideas that we hadn't had before."; "We really identified the crucial points."*) and reported strong spill-over effects (e.g.: *"I felt stimulated and noticed something was happening in my head.")*, especially due to stimulation by working the visual contributions in the CSS (e.g.: *"Writing on the cards virtually, something stirred in my head"; "A bit like looking inside the others' heads."*). Participants repeatedly clustered their results between work phases and reported that this helped them maintain a shared focus (*"That channeled the whole thing again")*. Several participants found collaboration and DP1 very time efficient (e.g.: *"Very impressive for such a short workshop"; "We would have come up with similar results otherwise, but probably not in the short time."*). This aligns with findings on time constraints, which enhance focus and encourage divergent thinking during collaborative tasks (Biskjaer *et al*., 2019). Structured pauses during the process regenerated participants' cognitive resources and promoted exploratory thinking, supporting radical creativity beyond routine problem-solving.

Table 7. Overview of the results of the DP evaluation

	Stage	Constraints	Proposition (Desired effects)	Results
DP1	General divergence	Sub-tasks parallel to main activity	Forget daily work (+)	(+/−) mixed
		– Repetition of sub-task	Spark radical creativity (+)	(+) supported
		– Reaction to others' contributions	Spill-over effects (+)	(++) strongly s
		Activity blocking between stages	Routine responses (−)	(+) supported
DP2	Whole process	Block distracting apps/functionalities	Focused activity (+)	(+/−) mixed
		– Visualization of remaining time	Efficient collaboration (+)	(++) strongly s
		– Proceeding w/limited overview	Engagement (+)	(+) supported
			Premature Discussions (−)	(−) supported
DP3	Later convergence	Mix groups during – Systematic integration	Shared understanding (+)	(+) supported
		– limited channels and speaking	Applicability of solutions (+)	(+) supported
			Psychological safety (+)	(+) supported
			Topic drift (−)	(–) strongly s
DP4	Initial divergence	Limited features (viable min.)	Engagement (+)	(+) supported
		– basic input, highlighting, navigation	Ease of use (+)	(+) supported
		– simple examples in work areas	Hesitancy to contribute (−)	(−) not supported
			Social facilitation (+)	(+) supported
DP5	Later divergence	Increase feature variety	Creative expression (+)	(+) supported
		– media input	Focused exploration (+)	(+/−) mixed
		– highlighting, connecting	Cognitive overload (−)	(+/−) mixed

Source(s): Authors' own work

While participants reported substantial effects on the stimulation of subsequent creativity and radical ideas beyond routine performance within work phases, limited or no effects were found regarding the overall immersion of participants ("forgetting their daily work") by blocking out external distractions. Successful management of external distractions may require adjustments based on the preferences and responsibilities of participants, for instance when working with leadership teams or domain experts. To achieve this, the timing and structure of breaks may be varied and allow for temporary distractions to help maintain engagement within work phases.

Based on these findings, DP 1 was adjusted with regard to the length of work phases and the timing of interventions between them. As participants were able to generate radical ideas beyond routine performance despite distractedness and limited levels of immersion ("forgetting daily work"), the according section was removed from DP 1.

3.3.2 Observations and findings for DP2 (principle of blocking and proceeding). While reminders to limit distractions were perceived as helpful, participants reported mixed levels of focus due to external distractions through email and coworkers during the experiment (e.g.: *"I let myself be distracted by emails, because I'm also in the normal working day"*). High levels of engagement during the experiment could be observed within the team from the beginning, with participants following each other and adding contributions, using a wide variety of colours, elements, and connectors. The majority of participants reported high levels of engagement (e.g.: *"Satisfying to see everybody engaged and posting ideas"*). Overall collaboration was perceived as very efficient compared to daily collaboration, mitigating unnecessary discussions at early process stages (e.g.: *"Everyone worked together very* *efficiently and with good suggestions"*). This is consistent with research demonstrating how structured tensions, such as limiting communication and enforcing stage-wise progress, can stimulate creativity by prompting participants to explore non-habitual paths (Onarheim and Wiltschnig, 2010). These structured constraints enabled participants to navigate limitations, supporting radical. According to the interview data, the interplay of individual immersion and sharing of ideas within the group over work phases benefited team alignment and shared understanding (e.g.: *"It was good to have time to cluster and classify the results together"*), but limited individual inquiry *("I would have liked a little more time to get to the heart of my thoughts"*).

As collaborators moved through clear stages while working under time constraints, the importance of visual clustering and highlighting of key information was apparent to move from "chaos to clusters" and support a shared focus and understanding within the team. As DP 2 offers little room for methodological improvisation, it requires a reliable level of existing knowledge of goals and methods within a team. While this group included only one participant with a leadership position and distractions due to external work demands occurred less, they still were a substantial challenge for some participants during the experiment.

Based on these findings, DP 2 was adjusted with regard to the limitations and importance of selective management of distracting applications and functionalities on collaborators' computers.

3.3.3 Observations and findings for DP3 (principle of mixing and integrating). Collaborators produced a high amount of output on the whiteboard during divergent work phases, which was initially perceived as confusing and even stressful for some participants (e.g. *"It was a bit rushed because time was limited"*). Similar to DP1 and DP2, repeated clustering emerged as a mechanism to maintain an overview along the work phases. Participants reported high levels of applicability of their final solutions (*"We have found three solutions that we are now implementing directly"*). No "creative leaps" were reported, which is in accord with the overall purpose of DP3. Overall, collaboration under time constraints was perceived as helpful in preventing topic drift during the experiment (*"We stayed with the topic the whole time because it was so condensed and crisp"*). During the experiment, participants perceived high levels of shared understanding and psychological safety, which helped substantially to avoid topic drift according to the interview data (e.g.: *"I think that's just in our team because we have a very good and trusting communication"*). Participants also reported high levels of familiarity with similar CSS, which was apparent with immediate activity and confident use of the CSS during the experiment. In order to generate subgroups of three to five collaborators, a total group size above seven is required. During the integration of the subgroups' ideas, not only individual speaking time was applied, but limited time for integration phases. Based on these findings, DP3 was refined with regard to group sizes and time management during later-stage integration.

3.3.4 Observations and findings for DP4 (principle of initial limitation). Participants reported high levels of engagement, which were observable in the CSS during the experiment (*"it was very easy for me to share ideas with others and to make a contribution"*). While the CSS was perceived as easy to use (*"I had a good overview and was able to navigate easily"*), some participants showed hesitancy to participate in order to avoid redundancy of ideas (*"I didn't want to write something again that was already there"*). Working around the constraints of the CSS in the earlier work phases (using features that were explicitly not to be used), work phases and -styles were confused by some participants on one occasion. According to the interview data, social facilitation emerged within the group and had a motivating effect, as intended by DP4 (*"I was very motivated to work with the others"*). While hesitancy seemed mainly caused by social factors, feedback within the group was limited due to perceived time limitations and a lack of traceability of individual contributions (*"I would have liked to see who wrote what and more easily identify where they were active on the board"*). Based on these findings, DP4 was adjusted with regard to better provision of overview over work phases (in order to prevent confusion) and the promotion of social facilitation.

3.3.5 Observations and findings for DP5 (principle of late variety). According to the interview data, participants felt that they could creatively express themselves within the CSS (*"We were able to express many ideas"*). While creative expression was supported as expected, creative experimentation was not perceived as possible within the CSS (e.g.: *"We did not have that much time to investigate and experiment with the ideas together due to timeboxing"*). In this regard, the importance of visualization to support traceability and feedback among collaborators was reported as important as in DP4. While DP5 allows for a large variety of visualization features, participants initially showed hesitance to "switch modes" when transitioning from feature scarcity to feature abundance. Over time, the use of visualization features increased substantially.

During the experiment, participants reported mixed levels of focus and cognitive overload, due to external distractions and discussions or explanations of other collaborators (*"I sometimes got distracted, especially during summaries or when two people discussed a lot with each other"*). Seeing different perspectives and contributions within the team had a motivating effect ("*Great to see how it built up like a swarm and then you suddenly generated a huge amount of data"*).

During the 90 min, moderate breaks of three to five minutes were perceived as helpful in maintaining focus and engagement (*"Those breaks were good to connect and chat, then focus again"*). However, after 60 min, a substantial loss of focus and activity was reported and observable within the CSS (*"At the beginning my concentration was high, later I looked more at my phone")*. As this bears the risk of cognitive overload, breaks should be applied more deliberately along the process. Based on these findings, DP5 was adjusted with regard to the support of creative expression and the application of short breaks. Based on these findings, the pre-test DPs were refined and adjusted (see Table 8).

4. Contribution and conclusion

In our research, we synthesized concepts and theories of collaborative creativity and explored the use of constraints by expert facilitators and creativity coaches. Based on semi-structured interviews, we derived user stories and MRs that we synthesized into five DPs. We then evaluated the DPs in an experimental workshop setting, leading to a refined and evaluated version of the principles. The results illustrate the impact of constraints in CSS on fostering more radical forms of creativity, encouraging adaptation and activity, and enabling expression and exploration for inexperienced users.

4.1 Theoretical contribution

We contribute by providing evidence-based, prescriptive recommendations for the design and application of constraints in CSS. Our research addresses a gap in design knowledge about whether and how constraints affect different stages of the creative process (Elder and Zhou, 2013; Medeiros *et al*., 2018). It extends previous research attempts to define a constraint dimension or continuum to support levels of constraint in the creative process (Onarheim and Biskjaer, 2015) that did not distinguish between analog and virtual application contexts and did not specify the underlying means-end relationships of constraints in a way applicable to the design of CSS. By relying on theories of creativity and creative collaboration, we demonstrated the potential of external, temporal constraints of varying complexity (Onarheim and Biskjaer, 2015), such as reducing complex behaviours to simple tasks or "tunneling" collaborators through a predetermined set of actions (Fogg, 2009).

Furthermore, we provide empirical evidence on the benefits and mechanisms of constraints in both convergent and divergent phases of the creative process, which hasn't been studied sufficiently before (Caniëls and Rietzschel, 2015; Medeiros *et al*., 2018). The positive effects of constraints on shared knowledge and improved task performance were found to be highly relevant in divergent phases of collaboration. By more intentionally distinguishing and

Table 8. Adjusted version of DP1-5 (adjustments to pre-test-version marked underline)

	Context Actor, instance, boundary condition	*Mechanism (M) and enactor (E)* Activity, process, manipulation of (sub-) components/artifacts	*Rationale (R)* Theoretical/empirical justification
DP 1 Stimulation and pause	*To spark radical forms of creativity beyond routine performance* during divergent phases in the context of virtual collaboration	M1) Employ sub-tasks that collaborators need to perform parallel to their main activities, M2) Enable the system to block activities *at points of decreasing focus* or after limited time periods, E1) Involve task repetition and celebrations of contributions	R1) To stimulate positive spill-over effects between explicit and implicit conscious processes, R2) *To prevent routine responses* by collaborators
DP 2 Blocking and proceeding	To promote focused activity and efficiency in the context of virtual collaboration	M1) *Selectively block distracting applications and functionalities on collaborators' computers*, M2) Make collaborators proceed through stages, E1) Involve the visualization of remaining time, E2) Limit overview of work areas and visibility of user activities	R1) To prevent distractions R2) To prevent premature discussions, R3) To promote engagement
DP 3 Mixing and integrating	To promote shared understanding and applicability of generated solutions during later stage convergent phases in the context of virtual collaboration within groups *larger than 7 or 9 participants*	M1) Enable collaborators to *create subgroups of 3 to 5* M2) Guide main group through a process of systematic integration of objections, E1) Involve limited channels, E2) *Limit time periods for individual speaking and interpersonal exchange*	R1) To prevent topic drift, R2) To promote psychological safety
DP 4 Initial limitation	To enable inexperienced users to engage during initial stages of divergent thinking in the context of virtual collaboration	M1) *Provide overview over work phases* M2) Limit available features to a viable minimum E1) Involve only basic functionalities for input, highlighting, navigation E2) Provide simple examples in work areas	*R1) To promote contributions, R2) To promote social facilitation within the group*
DP 5 Late variety	To enable inexperienced users to *express and specify* ideas during later phases of divergent creativity in the context of virtual collaboration	M1) *Provide overview over work phases*, M2) Increase feature variety, E1) *Involve short breaks*, E2) Involve various forms of media input, E3) Enable users to create, highlight and connect elements in multiple ways	R1) To prevent cognitive overload, R2) To promote focused exploration

Source(s): Authors' own work

addressing the specific characteristics of divergent and convergent work phases (Gabriel *et al.*, 2016), we contribute to the existing knowledge on how to limit media breadth and depth to appropriately facilitate creative collaboration via CSS (Gebbing *et al.*, 2022; Schmidt, 2010).

In addition, we address various challenges of creative collaboration due to social dynamics such as social loafing, production blocking, or lack of psychological safety (Johnson *et al.*, 2007; Mehmood *et al*., 2021; Nijstad *et al*., 2003; Zhu *et al*., 2019). For example, participants who worked with limited communication channels and were guided through systematic interactions perceived high levels of shared understanding and psychological safety, which significantly helped to avoid topic drift. Similarly, blocking activities and moving collaborators through stages of a collaborative process was found to be an effective mechanism for promoting, rather than inhibiting, team alignment and shared understanding. This contributes to previous research that illustrated how teams can collaborate creatively under constraints by using motivational, cognitive, and social mechanisms influenced by factors that determine, for example, searchability or perception of a constraint (Acar *et al*., 2019), but did not apply these findings in the context of virtual collaboration. Specifically, these insights align with activity theory, which suggests that collaboration emerges from resolving tensions and instabilities within a system (Kaptelinin and Nardi, 2012a). By addressing production blocking and social loafing through constraint-based interventions, our findings contribute to understanding how structured interaction design can mitigate common obstacles in virtual creative collaboration (Karau and Williams, 1993; Nijstad *et al*., 2003).

Our findings also show how constraints in CSS can substantially benefit the stimulation, generation, and exploration of ideas beyond routine performance and promote more radical forms of creativity (Madjar *et al*., 2011). Limited co-worker presence and availability, a combination of multitasking and activity blocking during exploratory phases, and limited functionalities and means of communication were found to facilitate the emergence of inspirational stimuli in CSS and help users access the instrumental potential of CSS (Carroll, 2003; Gebbing *et al*., 2022; Kaptelinin and Nardi, 2012a). Our findings further support activation theory by demonstrating that structured constraints can stimulate engagement, promote multitasking as a cognitive priming mechanism, and enhance creative output beyond routine performance (Baer and Oldham, 2006; Kapadia and Melwani, 2021). While participants reported substantial effects on stimulating subsequent creativity and radical ideas within work phases, limited or no effects were found on participants' overall immersion by blocking out external distractions.

Furthermore, we provide empirical insights into how constraints can be used to reduce cognitive load (Rodet, 2022), mitigate the negative side effects of feature overload (Adam *et al*., 2017; Chandra *et al*., 2019; Thompson *et al*., 2005), and support focus and productivity in virtual teams. We have shown how limited functionalities and communication tools can help mitigate the learning and application of technology for creative collaboration (Carroll, 2003; Kaptelinin and Nardi, 2012a), for example by reducing its complexity (Adam *et al*., 2017; Chandra *et al*., 2019; Tarafdar *et al*., 2007). Thus, we extend prior research based on media richness theory (Chao *et al*., 2020) by showing that reducing media breadth and depth at specific phases of creative collaboration can enhance focus and mitigate cognitive overload, thereby improving overall creative performance. We not only illustrate how constraints in CSS can reduce cognitive barriers to human reasoning in creative processes but also show how constraints, among other strategies, can successfully counter these barriers in the context of virtual collaboration. For example, our findings suggest that means of shared communication do not need to be available throughout the entire process, especially when collaborating creatively in rapid feedback cycles (Madjar *et al*., 2011). But can be more selectively timed to support coordination and thus prevent information overload (Carroll, 2003; Gebbing *et al*., 2022; Kaptelinin *et al*., 1995). This provides important empirical validation for the transferability of constraint-based, analog countermeasures and strategies (Butler and Roberto, 2018).

By offering a constraint-based perspective on CSS design, we extend the existing literature of design knowledge on CSS and IT-supported creativity and illustrate the need for careful reflection and extension of existing design knowledge for CSS (Müller-Wienbergen *et al*., 2011; Voigt *et al*., 2013). This extends previous research on CSS, which has emphasized the importance of open and simple exchange (Shneiderman, 2007, 2009) and rich communication (Voigt *et al*., 2013). While previous requirements and design principles in the context of IT-supported creativity have outlined that CSS should, for example, prevent evaluation apprehension (Kahn, 1990), they have not specified constraints in a prescriptive way with a specific purpose and mechanism.

4.2 Practical contribution

This study provides actionable insights for practitioners, including facilitators, CSS designers, but also decision-makers such as CIOs and CTOs, to design and implement constraint-based CSS. The proposed DPs serve as practical tools to address the challenges inherent in virtual and creativity-intensive collaboration. For example, the presence of other people can either increase individual motivation or lead to social loafing, where individuals exert less effort in group settings (Gebbing *et al.*, 2022; Siemon *et al.*, 2017). By leveraging the DPs, facilitators, and designers can address such issues by enabling idea generation in more isolated settings, minimizing production blocking, and supporting psychological safety. This ensures more effective collaboration, especially in divergent phases of the creative process.

By examining the requirements of CSS from a constraint-based perspective, designers can identify and utilize further and more effective strategies to mitigate the negative side effects of cognitive overload. Our findings highlight that limited functionalities and communication tools can enhance focus and reduce distractions during collaborative activities. For instance, participants who worked with limited communication channels and activity-blocking mechanisms reported improved team alignment and shared understanding. This demonstrates the practical value of selectively restricting certain features to facilitate coordination while preventing information overload. Additionally, the study provides facilitators with methods to better structure creativity-intensive workshops. By incorporating the proposed DPs, facilitators can design processes that alternate between divergent and convergent thinking phases, supported by modular constraints such as timeboxing, controlled interruptions, or guided progression. For example, our findings show how structured pauses (DP1) or systematically limiting communication during specific work phases (DP2) can promote creative focus and reduce cognitive load. These features align with strategies to enhance productivity and foster radical creativity, enabling teams to explore transformative ideas in a controlled yet flexible environment.

Our results also emphasize the transferability of constraint-based mechanisms from analog to digital contexts and vice versa. Workshop facilitators and system designers can use these findings to adapt CSS for specific use cases, tailoring functionalities to the needs of creativity-intensive teams. For instance, the ability to time shared communication or selectively introduce collaboration tools can help prevent feature overload and improve usability. By doing so, practitioners can develop more effective systems that balance flexibility with structured guidance, ensuring that CSS remains a reliable enabler of creativity and innovation. On the other hand, our DPs can inform in-person creativity workshops to make use of constraints.

In summary, our findings contribute a practical framework for operationalizing constraints in CSS design, offering designers and facilitators tested strategies to improve team coordination, foster radical creativity, and address challenges such as cognitive overload and social loafing in virtual collaboration settings.

4.3 Limitations and future research

Limitations of this research should be noted. First, the evaluation of the means-end relationship of each DP was evaluated independently which does not evaluate the combined effects of multiple DPs, i.e. what cross-effects can occur when implementing more than one DP. Further research is needed to understand the interaction between different DPs and their impact on creativity and innovation in virtual teams. Second, the low sample size of the study might limit the generalizability of the results. Constraints can affect people differently and consequently lead to different reactions in terms of their creative performance. To reduce potential confounding effects and minimize individual effects on humans, future studies should aim for higher sample sizes. Finally, the distracting potential of coworkers during creative collaboration was apparent across the DPs and groups, and further research is needed to understand the impact of distractions on the effectiveness of CSS in fostering creativity and innovation. These limitations highlight areas for future research and suggest avenues for improving the design and implementation of CSS to support virtual teams and enhance their creative problem-solving capabilities. While our DPs cannot satisfy all demands in creative collaboration, they can set important impulses when applied under the right conditions.

While this study provides valuable insights into the role of constraints in CSS design and their impact on creative collaboration, several avenues for future research remain. First, although the proposed DPs were evaluated in creativity-intensive virtual workshops, future studies could explore their applicability in other contexts, such as long-term team projects, hybrid collaboration settings, or cross-cultural teams. Investigating how constraints function in environments with varying levels of team familiarity, expertise, or diversity could provide further generalizability and refinement of the principles. Additionally, future research could explore other forms of implementing or instantiating the DPs, such as through alternative software platforms, low-code/no-code tools, or integration into existing organizational systems, allowing for more nuanced tests in diverse settings. Another promising area is the exploration of individual differences, such as cognitive styles or personality traits, to assess how users interact with constraints and how these dynamics influence creativity and performance. Finally, future work could consider the ethical implications of constraint-based design, especially regarding user autonomy and the potential unintended consequences of over-constraining collaboration. By addressing these gaps, future research can build on this study to advance both theoretical and practical understanding of constraint-based CSS design.

Appendix

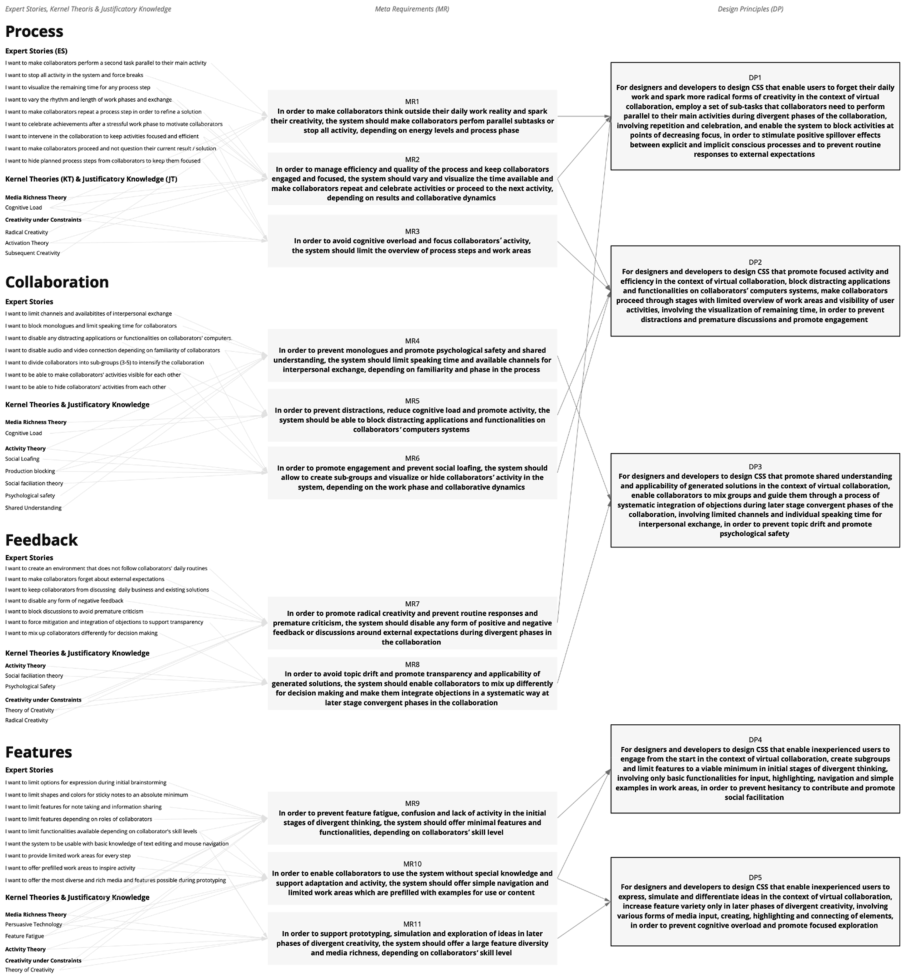

Figure A1. Mapping diagram. Source: Authors' own work, Möller *et al.* (2020)

Table A1. Derived expert stories (ES) from qualitative study

Category	#	Expert story (ES) *I want to . . .*
Process	ES1	*. . . make collaborators perform a second task parallel to their main activity*
Process	ES2	*. . . stop all activity in the system and force breaks*
Process	ES3	*. . . visualize the remaining time for any process step*
Process	ES4	*. . . vary the rhythm and length of work phases and exchange*
Process	ES5	*. . . make collaborators repeat a process step in order to refine a solution*
Process	ES6	*. . . celebrate achievements after a stressful work phase to motivate collaborators*
Process	ES7	*. . . intervene in the collaboration to keep activities focused and efficient*
Process	ES8	*. . . make collaborators proceed and not question their current result/solution*
Process	ES9	*. . . hide planned process steps from collaborators to keep them focused*
Collab	ES10	*. . . limit channels and availability of interpersonal exchange*
Collab	ES11	*. . . block monologues and limit speaking time for collaborators*
Collab	ES12	*. . . disable distracting applications or functionalities on collaborators' computers*
Collab	ES13	*. . . disable audio and video connection depending on familiarity of collaborators*
Collab	ES14	*. . . divide collaborators into sub-groups (3–5) to intensify the collaboration*
Collab	ES15	*. . . be able to make collaborators' activities visible for each other*
Collab	ES16	*. . . be able to hide collaborators' activities from each other*
Feedback	ES17	*. . . create an environment that does not follow collaborators' daily routines*
Feedback	ES18	*. . . make collaborators forget about external expectations*
Feedback	ES19	*. . . keep collaborators from discussing daily business and existing solutions*
Feedback	ES20	*. . . disable any form of positive and negative feedback*
Feedback	ES21	*. . . block discussions to avoid premature criticism*
Feedback	ES22	*. . . force mitigation and integration of objections to support transparency*
Feedback	ES23	*. . . mix up collaborators differently for decision-making*
Features	ES24	*. . . limit options for expression during initial brainstorming*
Features	ES25	*. . . limit shapes and colors for sticky notes to an absolute minimum*
Features	ES26	*. . . limit features for note taking and information sharing*
Features	ES27	*. . . limit features depending on roles of collaborators*
Features	ES28	*. . . limit functionalities available depending on collaborator's skill levels*
Features	ES29	*. . . the system to require only basic knowledge of text editing and mouse navigation*
Features	ES30	*. . . offer prefilled work areas to inspire activity*
Features	ES31	*. . . provide limited work areas for every step*
Features	ES32	*. . . offer the most diverse and rich media and features possible during prototyping*

Source(s): Authors' own work

Table A2. Derived design principles for the design of constraints in CSS (pre-test version)

	Context Actor, instance, boundary condition	*Mechanism (M) and enactor (E)* Activity, process, manipulation of (sub-) components/artifacts	*Rationale (R)* Theoretical/empirical justification
DP 1 Stimulation and pause	To spark radical forms of creativity beyond routine performance during divergent phases in the context of virtual collaboration	M1) Employ sub-tasks that collaborators need to perform parallel to their main activities, M2) Enable the system to block activities at points of decreasing focus or after limited time periods, E1) Involve task repetition and celebrations of contributions	R1) To stimulate positive spill-over effects between explicit and implicit conscious processes, R2) To prevent routine responses to external expectations

(*continued*)

Table A2. Continued

	Context Actor, instance, boundary condition	*Mechanism (M) and enactor (E)* Activity, process, manipulation of (sub-) components/artifacts	*Rationale (R)* Theoretical/empirical justification
DP 2 Blocking and proceeding	To promote focused activity and efficiency in the context of virtual collaboration	M1) Block distracting applications and functionalities on collaborators' computer systems, M2) Make collaborators proceed through stages, E1) Involve the visualization of remaining time, E2) Limit overview of work areas and visibility of user activities	R1) To prevent distractions, R2) To prevent premature discussions, R3) To promote engagement
DP 3 Mixing and integrating	To promote shared understanding and applicability of generated solutions during later stage convergent phases in the context of virtual collaboration	M1) Enable collaborators to mix groups M2) Guide them through a process of systematic integration of objections, E1) Involve limited channels E2) Limit individual speaking time for interpersonal exchange	R1) To prevent topic drift, R2) To promote psychological safety
DP 4 Initial limitation	To enable inexperienced users to engage during initial stages of divergent thinking in the context of virtual collaboration	M1) Create subgroups M2) Limit available features to a viable minimum E1) Involve only basic functionalities for input, highlighting, navigation E2) Provide simple examples in work areas	R1) To prevent hesitancy to contribute and R2) To promote social facilitation
DP 5 Late variety	To enable inexperienced users to express, simulate and differentiate ideas during later phases of divergent creativity in the context of virtual collaboration	M1) Increase feature variety, E2) Involve various forms of media input, E3) Enable users to create, highlight and connect elements in multiple ways	R1) To prevent cognitive overload, R2) To promote focused exploration

Source(s): Authors' own work

Table A3. Interview questions

About you (short statements sufficient)
How old are you?
What is your gender?
What is your highest completed education?
How long have you worked in this company?
How long have you been working in this team?
Are you an executive/do you lead others?
How familiar were you with MIRO before the experiment? 1: never used 7: I am an expert
How comfortable do you feel working with MIRO? 1: I am clueless 7: I am an expert

	Construct	Based on
DP1 questions about the workshop (Take a moment and describe your experience)		
How relaxed or stimulated did you feel? How Excited or Calm?	Stimulation	Kapadia and Melwani (2021)
How absorbed were you in what you were doing and didn't let anything else distract you?	Focused Immersion	Cherry and Latulipe (2014)
To what extent have you completely forgotten the rest of your day-to-day work?	Involvement	
To what extent do the resulting solutions show completely new ways that you have never tried before?	Radical Creativity	Madjar *et al.* (2011)
To what extent did you suddenly come up with new ideas that you didn't even think of?	Spill-over/Subsequent Creativity	Hess *et al.* (2006)
How restricted did you feel in the whiteboard system? Which other functions/options would have helped you?	Constraints	own

	Construct	Source
DP2 Questions about the workshop (Take a moment and describe your experience)		
How concentrated or distracted were you during the exercise?	Focused Activity	Cherry and Latulipe (2014)
How absorbed were you in what you were doing and didn't let anything else distract you?	Focused Immersion	
How efficiently did you work together and concentrated on the essentials?	Efficient Collaboration	He *et al.* (2007)
To what extent was everyone involved without getting bogged down in unnecessary discussions?	Discussion Quality and Engagement	Gilson *et al.* (2005)
How restricted did you feel in the whiteboard system? Which other functions/options would have helped you?	Constraints	own
DP3 Questions about the workshop (Take a moment and describe your experience)		
How well did you understand your topic together?	Shared Understanding	Johnson *et al.* (2007)
How feasible are the solutions you found?	Applicability of Solutions	Cropley *et al.* (2011)
How much did you stay on topic without losing focus?	Topic Drift	Runco and Acar (2012)
How comfortable did you feel sharing thoughts and ideas with others?	Psychological Safety	Kahn (1990)
How restricted did you feel in the whiteboard system? Which other functions/options would have helped you?	Constraints	own
DP4 Questions about the workshop (Take a moment and describe your experience)		
How well did you find your way around the app and were you able to work well from the start?	Ease of Use/Previous Experience	Venkatesh *et al.* (2003)

(*continued*)

Table A3. Continued

	Construct	Source
How easy was it for you to share your ideas with others and thus make a valuable contribution?	Contribution/Self-Efficacy	Ahuja and Webster (2001)
How did it motivate you to work with others and see how everyone contributes?	Social Facilitation	Amabile *et al.* (1990)
How restricted did you feel in the whiteboard system? Which other functions/options would have helped you?	Constraints	own
DP5 Questions about the workshop (Take a moment and describe your experience)		
How absorbed were you in what you were doing and didn't let anything else distract you?	Focused Immersion	Cherry and Latulipe (2014)
How easy was it for you to experiment creatively and explore different ideas/possibilities?	Self-Expression	Choi *et al.* (2009)
How restricted did you feel in the whiteboard system? Which other functions/options would have helped you?	Constraints	own

Source(s): Authors' own work

Note

1. https://www.miro.com is a visual collaboration tool (virtual whiteboard)

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