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Gonçalves, Milene; Cash, Philip

Published in:
Design Studies

Link to article, DOI:
10.1016/j.destud.2020.100988

Publication date:
2021

Document Version
Publisher's PDF, also known as Version of record

Link back to DTU Orbit

Citation (APA):
Gonçalves, M., & Cash, P. (2021). The life cycle of creative ideas: Towards a dual-process theory of ideation. *Design Studies*, *72*, Article 100988. https://doi.org/10.1016/j.destud.2020.100988

The life cycle of creative ideas: Towards a dual-process theory of ideation

Milene Gonçalves[1] and *Philip Cash*, Delft University of Technology, the Netherlands, Technical University of Denmark, Denmark

Ideation is simultaneously one of the most investigated and most intriguing aspects of design. The reasons for this attention are partly due to its importance in design and innovation, and partly due to an array of conflicting results and explanations. In this study, we develop an integrative perspective on individual ideation by combining cognitive and process-based views via dual-process theory. We present a protocol and network analysis of 31 ideation sessions, based on novice designers working individually, revealing the emergence of eight idea archetypes and a number of process features. Based on this, we propose the Dual-Process Ideation (DPI) Model, which links idea creation and idea judgement. This explains a number of previously contradictory results and offers testable predictive power.

Keywords: design cognition, creativity, conceptual design, design process(es), dual-process theory

Everything starts with an idea. Arguably, even the most innovative breakthroughs have humble origins as simple ideas, sketched on a post-it or piece of paper. Ideation is essential to the development of innovative products, services, and technologies (Chulvi et al., 2013; Römer et al., 2001). However, despite a rich body of ideation research (e.g., Shroyer et al., 2018; Sosa, 2019; Vargas Hernandez et al., 2010), there are a number of major conflicting results surrounding the creation and evolution of ideas.

First, the dual-effect of stimuli: design fixation and early attachment to initial ideas have been widely studied (e.g., Jansson & Smith, 1991; Youmans & Arciszewski, 2014; Vasconcelos & Crilly, 2016). However, while using examples in ideation can lead to design fixation, the use of stimuli in the design process is ubiquitous and necessary (Eckert & Stacey, 2000; Popovic, 2004). Second, the relationship between quantity of ideas and creativity: in creative practices, it is widely accepted that, by generating many ideas, there is a higher probability of coming to a creative solution (e.g., Osborn, 1953; Parnes, 1961; Paulus et al., 2011). However, there is also evidence that fewer ideas are positively correlated with higher originality (Heylighen et al., 2007; Kazakci et al.,

Corresponding author:
Milene Gonçalves
m.guerreirogoncalves@tudelft.nl

www.elsevier.com/locate/destud
0142-694X *Design Studies* **72** (2021) 100988
https://doi.org/10.1016/j.destud.2020.100988

2014), and that expert designers develop only single ideas in practice (Darke, 1979; Lawson, 2004; Crilly & Moroşanu Firth, 2019). Third, the difficulty in predicting ideas' uptake: although there are numerous studies that have examined how ideas are selected (e.g., Ritter et al., 2012), or how ideas evolve over time (Beaty & Silvia, 2012; Shroyer et al., 2018), there is little consensus on which ideas will be successful (Starkey et al., 2016). In particular, novel ideas are often abandoned (Rietzschel et al., 2010). These conflicting results, and the diversity in the level of granularity and lenses used to study ideation, point to a need for integrative theory (Ball & Christensen, 2018; Cash, 2018).

In answer to this need, the aim of this study is to resolve conflicting accounts of ideation by proposing an integrative model based in dual-process theory (e.g., Evans, 2008). Although dual-process theory is widely accepted as a basis for understanding human cognition and behaviour (e.g., Evans, 2008; Kahneman, 2011), its potential to bring clarity to design phenomena has only recently started to be realised (Badke-Schaub & Eris, 2014; Cash et al., 2019; Daalhuizen, 2014). Using this lens, we study 31 protocols of industrial design engineering students, where the progression of ideation is evaluated with respect to the two types of reasoning outlined in dual-process theory. Based on this, we explain how ideas form, develop, and gain or lose prominence over time; and further, propose a model that dissolves previously disparate accounts of ideation and offers potential explanative and predictive power.

1 Theoretical background and research framework

Ideation, especially in the context of industrial design engineering, broadly describes a set of activities related to the creation and development of goal directed ideas (Reinig et al., 2007) and is considered "*core to the innovation process*" (Cash & Štorga, 2015, p. 391). This falls at the intersection of design process and cognition (e.g., Hay et al., 2017). Specifically, the conflicting results outlined in the introduction have each been related to potential differences in the cognitive processing at play at different points in the design process (Cai et al., 2010; Gonçalves, 2016; Sowden et al., 2014). As such, the conflicting results highlighted in the introduction resist explanation using only a *process*-based approach. Hence, we adopt two different but complementary lenses through which we investigate ideation: one *process*-based and one *cognition*-based. In the following sections, we will introduce these two lenses before linking their most essential constructs in our research framework.

1.1 A process lens on ideation

The ideation process has been described as co-evolutionary, with designers iteratively exploring multiple knowledge spaces (e.g., Dorst & Cross, 2001; Maher et al., 1996) and creating bridges between them (Cross, 1997). This conceptualisation provides a critical insight: each idea is connected to prior ideas, whether this connection is implicit or explicitly recognised. Ideas can be considered interconnected nodes within a network, always co-evolving along with the problem representation and, thus, continuously evaluated, developed or discarded in relation to the problem space (and *vice versa*). Importantly, this helps clarify the concept of 'an idea'. Specifically, ideas must be considered in terms of two distinct dimensions: their *creation*, i.e., how ideas gradually mature over time (Sosa, 2019); and their *judgement*, i.e., how idea outputs are evaluated in context (e.g., Dean et al., 2006; Kudrowitz & Wallace, 2013; Sääksjärvi & Gonçalves, 2018; Simonton, 2012). Together, these dimensions can enable a description of ideas from creation and initial externalisation, through processing and maturation, to judgement and synthesis. However, despite co-evolution providing a compelling foundation for understanding the design related aspects of ideas and ideation, its nature remains descriptive, and its link to cognition implicit. In particular, this lack of integration with cognition means that co-evolution alone may not be enough to resolve the conflicting results. Thus, we now explore dual-process theory (Sowden et al., 2014; Stanovich et al., 2012) as a possible complementary lens for understanding design ideation.

1.2 A cognitive lens on ideation

A major model in cognitive psychology is the dual-process theory of reasoning (Evans, 2003). Increasing evidence has shown that there are at least two types of thinking processes (Evans & Stanovich, 2013): System 1 or Type 1, characterised by implicit, rapid, and unconscious processing, normally linked with intuition and association; and System 2 or Type 2, described as reflective, deliberate, slow, and conscious processing (e.g., Evans, 2008). Humans predominantly process information using Type 1, which enables us to quickly respond to our environment in an automatic and unconscious manner. However, Type 1 processing can be overridden by Type 2, when more deliberate judgement and decision-making are required (Evans, 2008). In general, intuition and experience (Type 1) take the lead, but are overruled by more deliberate processing (Type 2) when expected results are not encountered and change is required (Evans, 2008; Evans & Stanovich, 2013; Kahneman, 2011). However, cognitive errors may occur, especially when Type 2 processing fails to supress Type 1 processing when needed i.e. 'Override Failure' (Stanovich et al., 2008). Type 1 and Type 2 are closely coupled, and their respective influences can be difficult to distinguish (Evans & Stanovich, 2013). This model has been used to explain a wide range of cognitive and behavioural results across application areas (e.g., Kahneman, 2011) and has, in general, been shown to hold great predictive power (Evans & Stanovich, 2013). Thus, we can draw two main conclusions from current dual-process research: First, both intuitive and deliberate processing occurs in all activities; Second, the structure of these processes offers distinct explanations and predictions that should be general across activities.

The above conclusions are, to some extent, illustrated in the design research context by Badke-Schaub and Eris (2014), who proposed that design thinking involves both intuitive (e.g., gut reaction) and rational decision making (e.g., use of systematic methods). Further, dual-process theory has seen limited recognition in the creativity context. This links to the fact that creativity involves both associative (Type 1) and analytical (Type 2) processing (Howard-Jones, 2002), where changes between these two types occur depending on the context and task at hand (Sowden et al., 2014). Thus, although cognition has been repeatedly highlighted as a fundamental connector in design research (e.g., Hay et al., 2017), and dual-process theory is both important and relevant for understanding design (Badke-Schaub & Eris, 2014; Daalhuizen, 2014; Moore et al., 2014), links between dual-process theory and design research are only just starting to emerge (Cash et al., 2019; Kannengiesser & Gero, 2019).

1.3 Research framework connecting process and cognitive lenses

We propose that, using dual-process theory as a basis (Evans, 2008; Evans & Stanovich, 2013; Kahneman, 2011), it is possible to conceptualise the interaction that occurs between Type 1 and Type 2 processing (Section 1.2), in relation to the creation and judgement of ideas connected in an ideation process (Section 1.1). Therefore, the aim of this study is to understand the process of idea creation and judgement during ideation using a dual-process theory lens. The core constructs used in this work are: 'ideas' operationalised as nodes; the 'ideation process' operationalised as a growing network of ideas, influenced by external inputs (e.g., stimuli or problem requirements); and 'Type 1 and Type 2 processing' operationalised as the links between ideas within the network (Section 1.2). Type 1 and Type 2 are further differentiated as implicit versus explicit linkages. Thus, every 'idea' node represents both an output, at the moment of creation, and an input for subsequent ideas, where output and input are linked by cognition. Figure 1 illustrates this research framework.

2 Research method

Given the research aim, and extent of current theory, we adopt a theory building approach. Specifically, we explore the relationships between the key constructs in our research framework (Cash, 2018; Handfield & Melnyk, 1998) in order to develop an integrative model able to support testable propositions (Wacker, 1998). To do this we use in-depth protocol and network analysis of 31 ideation sessions, resulting from novice designers working individually in an ideation activity.

2.1 Sample and data

The 31 participants (17 female) were Master design students from the Industrial Design Engineering faculty (TU Delft, The Netherlands), with a mean

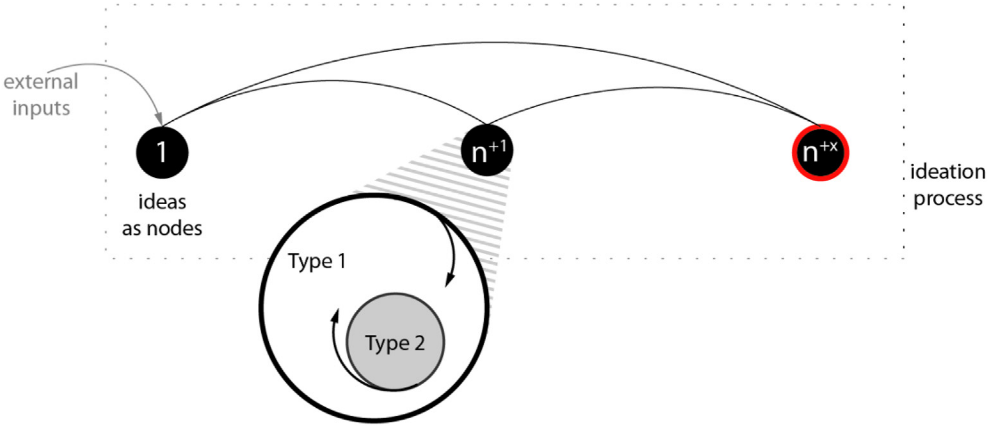


Figure 1 The research framework used in this study

age of 24. The participants reflected a range of nationalities, and reported having an average of five years studying design (with only four having prior professional experience). Students were used to increase internal validity (i.e., the extent to which evidence can support claims within a study). Students are usually homogeneous, highly motivated, and able to follow complex tasks, and are thus acknowledged to be superior for studies that prioritize internal validity (Druckman & Kam, 2011; Henry, 2008). Further, the size of the sample supported robust qualitative and quantitative analysis of within group effects (Onwuegbuzie & Collins, 2007).

Given the theory building approach, a qualitative multi-case logic was adopted (Handfield & Melnyk, 1998; Robson & McCartan, 2011, p. 154). Here, contrasting cases, where deliberately selected differences give insight into the theory of interest (Yin, 2013), provide robust analytical and theoretical generalisability (Robson & McCartan, 2011, p. 154). In particular, by contrasting cases it is possible to draw out insights regarding the determinants of different outcomes (Eisenhardt & Graebner, 2007). Thus, we allocated each participant to one of three conditions representing the three main situations in which individual ideation takes place: no available stimuli, limited access to stimuli, and unlimited access to stimuli. This allowed us to investigate the influence of stimuli in the ideation process, which is critically related to the conflicting results highlighted in the introduction.

- **No-stimuli ($N = 10$):** participants were only provided with the design brief.
- **Limited ($N = 11$):** participants were provided access to the stimuli search tool, but they could use it only *once* in the session.
- **Unlimited ($N = 10$):** participants were provided access to the stimuli search tool, which they could use as many times as they wanted within the time constraints of the session.

In order to control access to the stimuli, we used a previously described stimuli search tool (Gonçalves et al., 2016). For each session, participants were requested to sketch ideas and think aloud, following prior studies (Atman et al., 2005; Ericsson & Simon, 1993). Sessions were video recorded and transcribed, making it possible to synchronize idea production with verbalisation. Each session followed four steps:

1. **5 min introduction and warm up**: participants were briefed on the structure of the session. They completed a questionnaire with demographic information and did a small warm up exercise: to think aloud while sketching a picture of their house or room.
2. **30 min divergence**: participants were provided a design brief and asked to start a 30 min task with the aim to create as many different ideas as possible. The design brief was: *"Learning to sleep alone at night is a challenge for children at young age. Normally, until the age of two, parents keep their children close and have them sleep in a crib in the parents' room or even in their own bed. However, it is recommended that children make the transition to their own room and bed. Having the kids wake up during the night and come into the parents' bed is quite common and it is a big problem for parents. No one sleeps and rests conveniently, the child doesn't conquer his/her fears and parents don't have their privacy.* ***Your task is to design a product to help children of young age (3–5 years old) sleep alone through the night, in their own bed****."*
3. **10 min convergence**: immediately following divergence, participants were asked to "*generate one final concept to answer the brief*", i.e., elaborate a final concept.
4. **Interviews**: after completing the task, participants were asked questions about their ideation, use of stimuli, and approach. These semi-structured interviews ranged from 20 to 50 min.

The division of time of the sessions resulted from a series of pre-studies and follows the example of comparable studies (e.g., Cash et al., 2012; Rietzchel et al., 2010). The sessions took place in an experimentally-prepared room, with plain walls, equipped with three cameras, following similar prior studies (e.g., Cash et al., 2012). Cameras were arranged in such a way that sketch development, general behaviour, posture, and gesturing could be captured. Further, usage of the stimuli search tool was recorded with the Quick Time Player software.

2.2 Analysis of ideas

As participants were requested to sketch and take notes on paper, every idea could be recorded in terms of content, start time, and duration. This was facilitated by the use of a sheet with boxes specific to each idea, and separate paper provided for other actions for example, note taking. As such, each idea was characterised by sketching and keywords, coupled with verbal protocol analysis. The following coding excerpt exemplifies the start of an idea, its duration and its general level of detail (Figure 2).

An idea was considered to be concluded when the participant moved to another idea. Thus, participants were only considered to work on one idea at a time, with these idea segments forming the smallest unit of analysis in this research. This structure enabled the analysis of the wider ideation process by allowing individual ideas to be connected to other ideas, stimuli, or the design brief. However, not all of what was produced by the participants could be considered an idea. For example, mindmaps were used by a number of participants to outline the problem space. Thus, following prior definitions, we only considered ideas that were externalized with a clear purpose and function (Dean et al., 2006; Gonçalves, 2016; Shah et al., 2003).

2.3 *Analysis of the ideation process*

For each of the 31 participants, the ideation process was analysed, with the goal of understanding how each idea was related to prior and subsequent ideas as well as to external stimuli. As such, we described links between ideas as well as to keywords used in the search tool and stimuli retrieved from it. Further, we distinguished between implicit and explicit links defined using the following criteria, as a way to distinguish between Type 1 and Type 2 processing, respectively. *Implicit* links between items were established whenever:

- There were functional, behavioural or structural similarities (Hatcher et al., 2018; van der Lugt, 2000). These could be clearly identified in the participants' sketches, as different elements of initial ideas were included in subsequent ideas, but participants did not explicitly refer to them.
- A subsequent idea was a variation of a prior one and occurred within the same stream of thought (recognisable by the participant's discourse, following Hatcher et al., 2018).
- Parts of one idea were used in a different context, following the example of Baker and van der Hoek (2010), but reuse was not acknowledged by participants, indicating they might have not been consciously aware of them.

Figure 3 illustrates an implicit link between three ideas of a participant. All three ideas had common functional and behavioural features (the rocking of the crib was automatically activated by sound), although this link was not explicitly acknowledged by the participant.

01:04:00	hmm, what next...
01:06:00	to feel comfortable, safe, let him sleep
01:18:00	maybe a… like… something that like a device.
01:26:00	Maybe incorporated in the pillow, maybe
01:30:00	that records his mom's voice
01:34:00	so like, coming from here
01:41:00	yeah, sleeping
01:48:00	so while he tries to get asleep he can hear this kind of voice recording
01:57:00	[end of the idea and moving on to another idea]

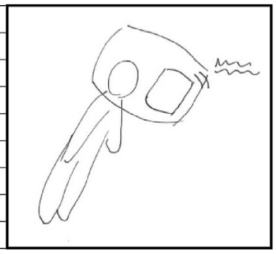
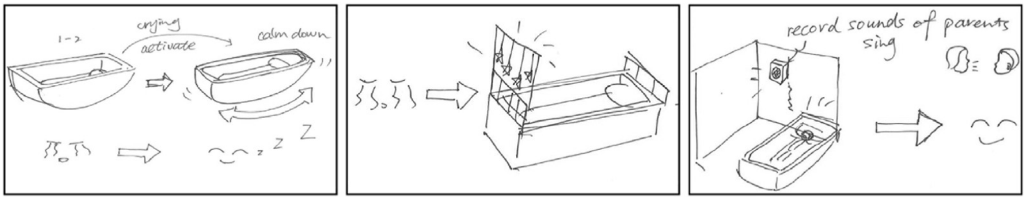


Figure 2 Idea coding excerpt from participant Limited 4

00:13:00	Well, first I come [to] the cradles they used when they rest (...)
00:31:00	So… When they are (...) one to two years old, when they wake up and start crying, their parents will always [rock]
00:48:00	the cradle to make them sleep again
00:57:00	So I think I can design an automatic cradle... when they begin to cry when they wake up, then the cradle can...
01:22:00	use sound to... check
01:26:00	So, when they are **crying they activate the [rocking] of the cradle** to let them calm down
02:08:00	Then…
02:45:00	**[Moving to idea 2]** And the, the second one I think about is some toys, uhm, that can illuminate...
02:58:00	so when they **begin to cry, they will see** this something,
03:14:00	for example, [that] hangs on the bed, like stars or something,
03:38:00	it begins to illuminate, then they get relaxed and feel more comfortable
04:24:00	**[Moving to idea 3]** Maybe also something in their rooms, to make the sound of their parents
05:03:00	So when **they cry, the sound activates**
05:18:00	the parents sounds ... uhm, can sing a song... Uhm, the parents can record something into the terminal
05:54:00	So it can make the kid feel that his parents are around him so he will fall asleep again.



idea 1 idea 2 idea 3

Figure 3 Implicit link coding excerpt from Limited 6

In contrast, *explicit* links were established between items (ideas, stimuli and keywords) whenever:

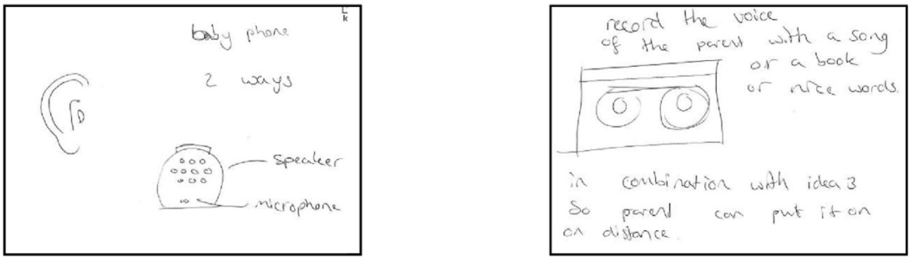
- Participants explicitly verbalized that item X (previous idea or stimulus) reminded them of idea Y.
- Participants wrote down keywords that referred to previous ideas or stimuli from the search tool.
- Participants visibly gestured towards a previous idea or stimulus when creating a new idea (van der Lugt, 2000).
- Participants started an idea immediately after or while using the search tool.

Figure 4 exemplifies an explicit link, where a participant goes back to an earlier idea (idea 3) to draw parallels and to build upon the current idea being generated (idea 6). As such, the combination of both ideas is a rationalisation (Type 2) process (Sloman, 1996, 2002).

Explicit and implicit links have been analysed following prior work by Sloman (1996, 2002) and Cash and Kreye (2018), as a way to distinguish between analytical (Type 2) and intuitive (Type 1) processing, respectively. Explicit awareness of one's thinking process and its outcome has been associated with deliberate and analytical Type 2 processing, while implicit thinking – when one is aware of one's actions but not of the reasoning process – is associated with intuitive and automatic Type 1 processing. Thus, as processing is not directly observable, this coding is an accepted approximation for empirically distinguishing Type 1 and 2 in protocol data.

The criticality of ideas was evaluated based on their influence on the ideation process network in terms of their total number of links. This follows recent network-based evaluations of design processes (Cash & Štorga, 2015), but also relates closely to 'critical moves' in Linkography. These are moves that are rich in links, to following ideas (forelinks), past ideas (backlinks), or both (Hatcher et al., 2018; Kan & Gero, 2008). As such, by coding idea nodes, and their linkages we are able to generate a robust representation of the ideation process, able to represent both how ideas are created and connected, and how these ideas are evaluated, judged, and synthesized, via a consistent framing of linkages directly related to dual-process theory.

12:28:00	uhm
12:35:00	not feeling their parent, ah I have a good idea **[starting idea 6]**
12:44:00	well you can record, at your cassette, because [laughing] something like this
13:03:00	uhm, record the voice of, uhm, of the parent
13:17:00	with a song... or a book... or nice words
13:28:00	it can say to the child if they're scared, so, and they can put it on themselves, so, they have to learn,
13:47:00	maybe it could be in combination with the **idea 3**



idea 3 idea 6

Figure 4 Explicit link coding excerpt from Limited 2

The life cycle of creative ideas

In order to ensure reliability, the two authors coded the same two sessions individually. Afterwards, we engaged in several iterative rounds, where we meticulously discussed the coding of implicit and explicit links, based on the participants' sketches, protocols, and their gestures/behaviour. The resulting codes were compared and discussed in order to tackle any discrepancies. After 100% agreement was reached, the first author continued the coding of all remaining sessions. Figure 5 illustrates an example of this analysis, with ideas arranged in time order and as nodes in the ideation process network, similar to Linkography. Explicit links are represented in black, on top, and implicit links are in grey, at the bottom.

3 Results

Our results are divided into three parts. First, we investigate how individual ideas can be distinguished. Second, we examine the ideation rate, i.e., the amount of ideas produced in relation to the time spent in the ideation session. Finally, we explore the ideation process as a whole.

3.1 Distinguishing ideas

At this level, ideas were analysed in terms of their interconnectivity with the rest of the ideation process network, using forelinks and backlinks. This allowed us to identify distinctly different types of ideas during ideation, and suggest their role in the process.

There were 409 ideas produced across the 31 participants. These were qualitatively clustered based on their positioning and role in the process networks. For example, early ideas often linked to many subsequent ideas and were thus clustered under the name *Shaping Ideas*. This followed an iterative refinement of clusters based on their ability to describe the full set of recorded ideas and process structures observed in the data. This resulted in eight qualitative clusters reflecting distinct types of ideas: *Shaping Ideas; Incremental Ideas;*

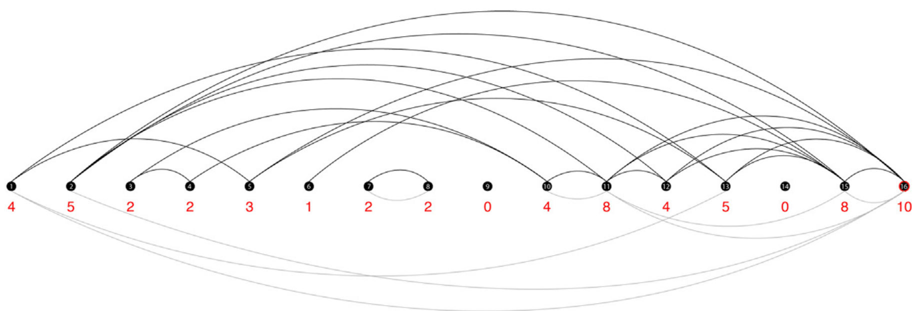


Figure 5 Example of an ideation process analysis, from Control 3. This participant produced 15 ideas and one final concept. The number of links to an idea (how critical it was) are noted under each in red

Tangent Ideas; Bridging Ideas (which were further separated into *Balanced*, *Foresight*, and *Hindsight*); *Combinatorial Ideas*; and *Final Combinatorial Ideas*.

Given the large number of observed ideas it was also possible to confirm these clusters using K-Means. Following the qualitative analysis, ideas were clustered based on the number of forelinks and backlinks (normalised by the total number of links in the network for comparability across participants), as well as what these links connected to: another idea, a stimuli, or other (e.g. a mind-map or the brief). Three methods were used to evaluate if the eight qualitatively identified clusters were quantitatively supported. First, eight clusters corresponded to the best Calinski–Harabasz pseudo-F value (2128.75) (Calinski & Harabasz, 1974). Second, the Calinski–Harabasz pseudo-F showed a strong 'elbow' around the ~2000 range with eight clusters falling at this point, when examining 2 to 15 possible clusters. Finally, the Duda–Hart test for 1 to 16 possible clusters again showed eight clusters as the best solution, with the largest Je(2)/Je(1) (0.9146) and smallest pseudo T-squared (2.99).

Eight clusters thus provide both strong qualitative meaning, as well as robust quantitative support. Each type of idea is illustrated in Table 1 together with examples from participants' ideation sessions. Here, number of fore- and backlinks are derived from the quantitative cluster analysis. The types of ideas are defined as follows:

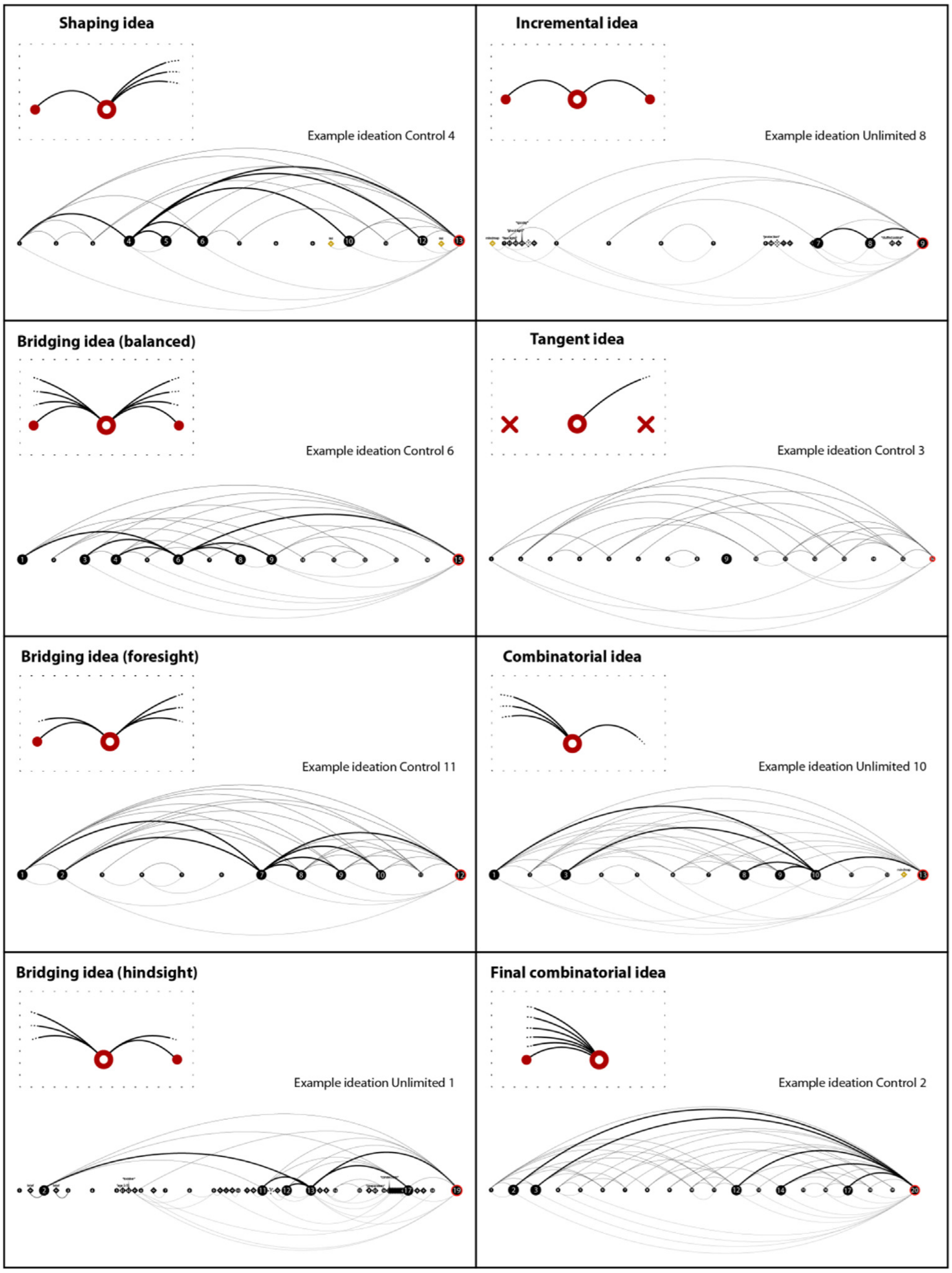
Shaping Ideas appear usually early in the process and are influential on subsequent ideation, with few backlinks. They are characterised by multiple forelinks across the process, and deal with key aspects of solution function, behaviour or structure.

Incremental Ideas make small additions from one idea to the next. They are still considered to be single ideas but their enhancements are closely tied to the previous idea.

Tangent Ideas have no backlinks to previous ideas and little connection to subsequent ones. They tend to diverge from the initial problem and solution space defined by the designer.

Bridging Ideas normally occur in the middle of a session and bridge multiple fore- and backlinks, resulting in a high number of connections and impact on the overall process. They can be further distinguished between **Balanced** (with a similar number of fore- and backlinks), **Foresight** (with more forelinks) or **Hindsight** (with more backlinks).

Table 1 Eight idea archetypes, with participants' mappings as examples for each



Combinatorial Ideas connect many previous ideas from a session. However, they are not yet final concepts, simply ideas where major convergence occurs, before continuing with ideation.

Final Combinatorial Ideas are similar to *Combinatorial Ideas*, but occur at the end of the session. All participants produced a final concept based on the combination and elaboration of prior ideas, which resulted in many implicit and explicit backlinks.

3.2 Ideation rate

As a second step in our analysis, we examine the amount of ideas produced by the participants in relation to the time spent in the ideation session. The focus of this analysis was on the 30-min diverging phase, because the final converging phase (10 min) was invariably concerned with only one idea, the final concept. Specifically, we have compared the amount of ideas generated in the first 5 min, in relation to subsequent 5-min segments, using a repeated measures ANOVA. This allowed for a comparison of ideation rate across the session. Table 2 gives the average number of ideas generated across participants in each 5-min segment (independently of the condition). Our results show that there was a statistically significant effect of time in the number of ideas generated ($F(5, 155) = 9.62$, $p < .0001$), with the first 5 min accounting for more ideas (an average of 2.97) than any other segment.

These results, coupled with Table 1, suggest that the first ideas were more effortless and flowed at a faster pace than subsequent ones, as they reflect the immediate associations participants had when reading the brief. Moreover, the ideation rate decreased considerably over time, which might indicate that later ideas required more deliberation, and hence a lower rate, in comparison to the initial ideas. Notably, these initial ideas (produced in the first 5 min) were invariably *Shaping Ideas*, which have a considerable impact on the generation of the final concept (Table 1). This, coupled with the fact that almost every participant produced ideas in the first and second minutes (often two or three ideas), strongly supports the link between initial ideas and fast, associative processing (Type 1), and later ideas and slower, more deliberate processing (Type 2).

3.3 Observations of dual-process ideation

Taking the idea clusters and ideation rate results as a starting point, iterative thematic analysis was carried out at the ideation process level. Here, both authors first carried out open coding to derive qualitative themes from the raw video and other data (Neuman, 1997, p. 511). This was followed by four rounds of cross-case analysis, which identified and refined key themes using

Table 2 Mean and standard deviation of ideas generated in the diverging phase in 5-min segments

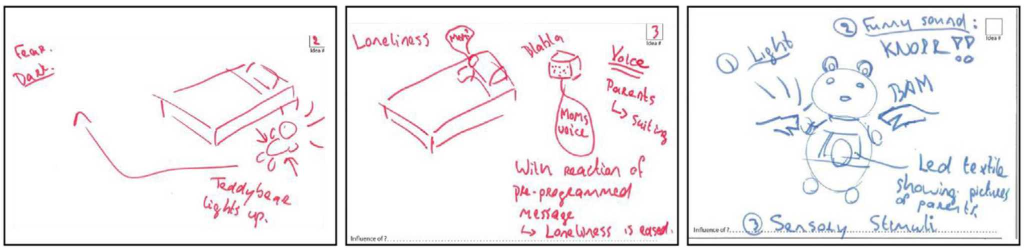
	1st 5 min	*2nd 5 min*	*3rd 5 min*	*4th 5 min*	*5th 5 min*	*6th 5 min*
Mean of Ideas	2.97	2.03	1.78	1.69	1.53	1.69
SD	1.43	1.20	0.87	1.12	0.92	1.20

axial coding (Neuman, 1997, pp. 512–514). Here, themes were iteratively refined by contrasting data from each of the stimuli conditions (Section 2.1). Ultimately, this resulted in four themes that each elaborates an aspect of our initial research framework (Figure 1). The themes are: *Closed-loop ideation*; *Incremental middle*; *Sacrificial reframe*; and *Combinatorial preference*.

3.3.1 *Theme 1 – closed-loop ideation*

Across participants and conditions, we consistently observed a strong connection between the first initial ideas and the final concept. Specifically, the first three ideas were connected to the final concept by both explicit (Type 2) and implicit (Type 1) links in all processes, as illustrated by the mappings shown in Table 1.

This theme is characterised and supported by the *Shaping Idea* and *Final Combinatory Idea* clusters (Table 1). For example, from the 31 processes, 25.8% of the first ideas involved some sort of teddy bear, and that number increased to 48.2% if we consider the first three ideas. Variants of plush toys were then evident in almost all the corresponding final concepts elaborated in the converging phase. Figure 6 shows such a case. This theme can be generalised to three main features. First, the initial ideas were almost always obvious for the problem at hand (e.g., a teddy bear), which suggests a predominance of Type 1 intuitive and associative processing. This is further supported by the ideation rate results, where these ideas were generated within the first moments of the session, again indicating Type 1 fast and associative processing. Second, participants frequently described the initial ideas as first explorations of the solution space and 'getting obvious ideas out there' with the subsequent aim to be more creative in following ideas, as exemplified in the following quote: "*Because I know that it's really important to just write everything down even if you think it's a bad idea, doesn't matter because … even better if it's a bad idea. Because then you got rid of it. You get rid of stuff by writing it down*" (Limited 7). This points to an initial focus on intuitive Type 1 processing. Third, the initial ideas were produced without use of stimuli, as participants tended to first rely on personal experiences and knowledge, shared



idea 2 | idea 3 | Final concept (idea 11)

Figure 6 Ideas 2, 3, and final concept of Control 5, showing the influence her first ideas on her final concept culture, and prototypical solutions. This again links to rapid Type 1 associative processing. Together, these suggest a dominance in Type 1 processing and a lack of deliberate rule-based reasoning (Type 2) during the generation of these initial *Shaping Ideas*. Thus, despite the initial ideas being non-novel, and recognised as such by participants, they still exerted a high degree of influence on the ideation process, and the final concept in particular.

3.3.2 *Theme 2 – Incremental Middle*

We observed a sequence of *Bridging Ideas* (Table 1), defined by the repeated variation of elements, both implicitly (Type 1) and explicitly (Type 2). Here, ideas incrementally evolved, as the participants systematically explored the solution space, based on slightly different interpretations of the problem, whilst still linking to the initial *Shaping Ideas*. While the *Incremental Middle* is characterised by some use of stimuli, which adds additional perspectives to the ideas at hand, it tends not to have long-lasting effects, i.e., few of these ideas are heavily linked to later ideas or the final concept.

This sequence of ideas was again observed across sessions, and combined the clusters *Incremental Idea* and *Bridging Idea* (*Balanced*, *Foresight* and *Hindsight*). As such, the ideas composing the *Incremental Middle* have short and long links that show an evolution of the thinking process of the designers, corresponding to small enhancements from one idea to the next (*Incremental Idea* cluster) and/or slightly longer bridges (*Bridging Idea* cluster), when a sequence of many ideas are connected. Here, participants used strategies, such as mindmaps, to guide their systematic exploration, where each idea is a slight variation of the previous one. This is illustrated in Figure 7, where the participant made incremental changes from one idea to the next (from a heat conducting pillow, to a sound generating pillow, to a musical chair, to life-size dolls shaped like the child's parents). Throughout, they used their previous ideas and mindmaps as memory aids to help continue production of ideas. This example illustrates the deliberate and careful combing of the solution space, to identify as many ideas as possible with the same features/functions, which

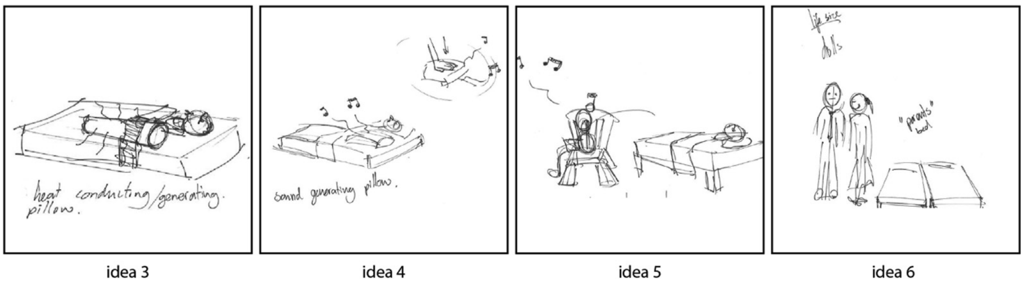


Figure 7 Example of 4 sequential ideas by Control 6, which incrementally build on each other

is indicative of analytical, rule-based Type 2 processing. This is further supported by the results presented in Section 3.2, which indicates that ideas produced later in the session were created at a slower and more effortful rate.

3.3.3 Theme 3 – sacrificial reframe

We observed situations where participants attempted to deliberately break free from their initial *Shaping Ideas* as well as from prior *Bridging Ideas*. This was defined by the generation of ideas with no backlinks, and could be considered as reframing, sometimes involving the use of stimuli. However, mirroring their lack of backlinks, these *Tangent Ideas* typically had few or no forelinks and rarely contributed to the final concept.

This theme was strongly based on the *Tangent Idea* cluster (Table 1), and was again repeated in almost all sessions, typically in the late stages of divergence just prior to convergence. Further, they were generated at moments when participants later reported that they were feeling 'stuck' and had difficulties proceeding: *"this is not really an idea, this is just me drawing trying to create more ideas. (…) These are points where I actually ran out of ideas and was like 'ok, I should just draw something' (…) And then here (idea 9) I ran out of ideas. I was just like 'ok, I need to pick something, very specific, and if I can just draw that, then maybe something else will pop up'"* (Control 4). This points to an application of deliberate rules in order to support ideation, i.e., Type 2 processing. Figure 8 shows an example of a *Tangent Idea* being generated. Further, while these ideas did not directly influence subsequent ideas or the final concept, they did play an important role in participants' rationalisation of their own creativity in the ideation process. Specifically, to a greater degree than *Bridging Ideas*, participants deliberately developed *Tangent Ideas* to help justify that they had indeed been creative and reframed the problem: "*So when I generate this idea I know that I was joking to myself but it was actually a solution. (…) So that's like and icebreaker. I mean these crazy ideas are not valid but they might have something that you might use. (…) So this is maybe like the idea that I want to make but this is too unrealistic. (…) Maybe meanwhile something is coming up"* (Control 10). Hence, both the generation and reflection on these ideas were strongly linked to deliberate Type 2 processing and rationalisation.

21:20:00	okay, it's not a good idea, but a lock on the door…
21:26:00	so kids can't get in,
21:29:00	it's a terrible idea
21:31:00	maybe there's like a secret, secret, ehh, knocking method that the
	kids have to figure out
21:40:00	by the time they actually try out the puzzle, maybe it's a puzzle,
21:44:00	okay, so there's a door,
21:46:00	by the time they figure it out they are already tired and they want to go to bed

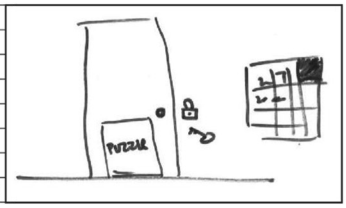


Figure 8 Example of a Tangent Idea *from Control 4 supported by deliberate effort to draw out new ideas*

3.3.4 Theme 4 – combinatorial preference

Finally, we have observed a *Combinatorial Preference* regarding the development of the final concept, which corresponds to a *Combinatorial Idea* followed by a *Final Combinatorial Idea* (Table 1).

This sequence was present in all sessions, and notable due to the coupling of the two combinatorial idea clusters in the final two ideas. While all participants received the same instructions, to elaborate on a final concept, the great majority of participants decided to combine ideas. Invariably, the final concepts were composed by parts and details of prior ideas, which tended to be heavily connected to the initial *Shaping Ideas*, as illustrated in Figure 9. This process typically involved the intercalation of Type 1 and 2 processing: after a first analysis of all ideas generated, there was generally a rapid production of a final idea with little explicit verbalisation (indicating Type 1 processing) followed by more deliberate rationalisation, elaboration, and detailing with extensive verbalisation (indicating Type 2 processing). Hence, this theme suggests a combination of processing types lead by Type 1 synthesis.

4 Discussion

In order to answer our research aim (section 1.3), we first discuss our major results individually, before synthesising them in Section 5.

4.1 Idea archetypes

The eight idea archetypes (Table 1) offer a consistent explanation of previously contrasting descriptions of creative ideas found in the design literature. For example, Darke's description of "primary generators" connect to our identified *Shaping Ideas* (Darke, 1979; Lawson, 2004), due to their strong influence on the rest of the ideation process. Similarly, our *Tangent Ideas* connect to

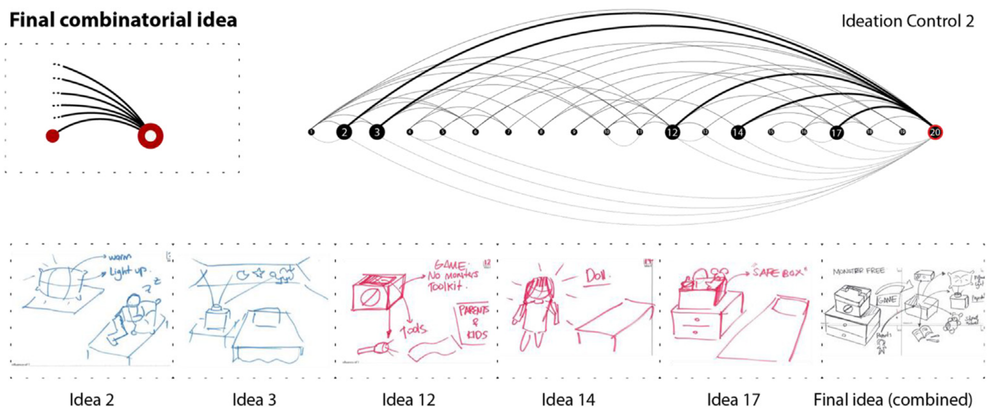


Figure 9 Example of an ideation process where the final idea is a combination of elements from prior ideas, including the initial Shaping Ideas *(Control 2)*

prior descriptions of "goal-oriented doodling" ideas (Gonçalves, 2017) as well as the use of ideas as "icebreakers" or attempts to explore the solution space. There are also parallels with van der Lugt's "tangential links" (Hatcher et al., 2018; van der Lugt, 2000), defined as moves that involve novel associations, which break away from previous directions. Further, our *Combinatorial (Final) Ideas* could be linked to the notion of "conceptual combination", defined as the "*combination of previously separated concepts (…) that come to mind most readily*" (Ward et al., 2002, p. 210). Thus, the observed archetypes connect to a range of prior descriptions in the design literature.

Importantly, the idea archetypes also appear to have consistent connections to dual-process conceptualisations of ideation when contextualised within the ideation process. Specifically, our thematic results (Section 3.3) highlight how the idea archetypes link to distinct processing regimes. For example, dominant Type 1 processing, where *Shaping Ideas* are rapidly produced via 'gut' associations (Section 3.3.1) or Type 2 processing following Type 1, where *Bridging Ideas* are deliberate developments of an initial solution (Section 3.3.2). Thus, our eight idea archetypes form a foundation for: 1) Delineating discussions of idea definition, 2) Illustrating the interaction between forelink creative processes and backlink judgment, and 3) Exploring the connection between individual ideas and dual-process based ideation. Given this, we now discuss these relationships in each theme.

4.2 Theme 1 – closed-loop ideation

This theme was characterised by a closed loop that connected the earliest ideas with the final concept generated by the participants (see the examples in Table 1). It is surprising to observe the ubiquity of this phenomenon across participants and conditions, especially considering prior literature. For instance, Osborn stated that "*early ideas are unlikely to be the best ideas generated during an ideation session*" (1953, p.132). While our results would support the evaluation that initial ideas are not the best in terms of novelty, we nevertheless find them to be highly influential. Similarly, our findings seem to contradict some of the most prevalent explanations of ideation, such as Parnes' principle of extended effort (1961), investment theory of creativity (Sternberg & Lubart, 1993) or bounded ideation theory (Reinig et al., 2007). For instance, Basadur and Thompson (1986) reported that, in managerial contexts, the most preferred ideas come from the later stages of the ideation project. However, these authors have not investigated how ideas develop over time or the influence of early ideas on later ones. In our data, participants produced these influential initial ideas very quickly, with little deliberation, while explicitly dismissing their importance (Section 3.3.1). Thus, there is strong evidence linking these initial ideas to associative Type 1 processing (Evans, 2008).

Given this associative response and the subsequent influence of the initial ideas they can be considered 'primary generators' – ideas or guiding principles that dominate the solution space from the start of one's process (Darke, 1979; Lawson, 2004). This corresponds to the continual influence of Type 1 associates, embedded in experience and knowledge (Evans & Stanovich, 2013). Further, as Type 1 processing reflects deeply rooted associations, it is possible to argue that these are also easier to accept when judging ones' ideas, which also draws heavily on Type 1 processing (Stanovich et al., 2008). As Darke articulated in design, a primary generator "*is not rejected unless there is a fairly glaring mismatch between it and the detailed requirements*" (Darke, 1979, p. 38). This is despite most participants being deliberate in their convergent work, corresponding to Type 2 processing (Evans & Stanovich, 2013). Thus, this theme would suggest that Type 2 processing during convergence might not have been enough to override Type 1 associations in the initial ideas, corresponding to dual-process explanations of Override Failure (Stanovich et al., 2008), i.e., when Type 2 processing is unable to suppress and offer a substitute to a Type 1 response.

4.3 Theme 2 – incremental middle

This theme emerged from heavy connections between ideas in the middle part of the ideation sessions. The *Incremental Middle* seems to have helped the participants to 'rationalise' that enough divergence had occurred, and was both slow and deliberate in the production and variation of ideas (Figure 7), corresponding to Type 2 processing (Evans & Stanovich, 2013). The systematic exploration of the solution space is a known strategy, described by many prior studies (Cross, 1997; Dorst & Cross, 2001). However, while these ideas did expand the solution space, they had a much more limited impact on the final concept, perhaps reflecting a difficulty in recombining them with the primary generators set out in the *Shaping Ideas*, and a conflict between Type 1 and Type 2 processing (Evans & Stanovich, 2013). Thus, the *Incremental Middle* that we have observed seems to correspond well with accounts of Type 2 processing, as well as prior design results.

4.4 Theme 3 – sacrificial reframing

Sacrificial Reframes, diverged from prior ideas, and occurred late in the ideation process, and would thus be expected, following prior research, to strongly influence the final concept (e.g., Parnes, 1961; Basadur & Thompson, 1986). Contrary to these expectations, these reframing attempts were not successful, even when supported by deliberate stimuli use, and were overtaken by links to the initial *Shaping Ideas*. Further, the true impact of these *Sacrificial Reframes* seems to have been in supporting rationalisation for the *Shaping Ideas*, rather than to actually reframe the problem/solution, hence we term them 'sacrificial' (Figure 8). Thus, while participants were consistently able to create highly novel or unexpected ideas, these were not considered when converging towards the final concept. This seems to be a common phenomenon, even in design practice, with Kelley and Kelley, from the worldwide leading design company IDEO, referring to it as 'sacrificial concepts', because "sometimes the craziest ideas (…) can lead to valuable solutions" (Kelley and Kelley, 2014). According to them, this refers to the deference of judgement, a well-known maxim to enable exploration of breakthrough ideas.

While this superficially conforms to the 'rejection of creativity' and selection of more feasible ideas as described by Starkey et al. (2016), *Tangent Ideas* were inherently different, but not necessarily less feasible than *Shaping Ideas*. Rather, reframing was slow and deliberate as was the subsequent justification that creativity had taken place, directly linked to Type 2 processing. As such, this connects to the *Closed-loop Ideation* theme by helping participants justify the continuation of their initial *Shaping Ideas* during a creative task, and supports the suggested Override Failure explanation in Section 4.2. Even though our results indicate substantial Type 2-led reframing, Type 1-dominated reframes seem to be possible as well, as demonstrated by past psychology and creativity studies on moments of insight or 'aha' moments (e.g., Akin & Akin, 1996). Such moments of insight, apparently led by intuitive reactions, were not observed in our dataset. Thus, we posit that *Sacrificial Reframes* are just one possible type of reframing, with a distinct role in the ideation process.

4.5 *Theme 4 – combinatorial preference*

The *Combinatorial Preference* theme reveals how, even during deliberate convergence, participants were still heavily influenced by the ideas produced more intuitively. While this could have been biased by asking participants to switch to a convergent mindset, the instructions were to "*generate one final concept to answer the brief*", which allowed participants freedom to adopt any strategy. Convergence is normally characterised by refinement and elaboration strategies that narrow down the problem and solution space, based on requirements imposed by the problem or reframed by the designer (Design Council, 2004; Runco & Basadur, 1993); or the deliberate combination of idea components (Gero, 2000; Sosa, 2019). As such, designers tend to apply more deliberate and explicit reasoning, which is associated with Type 2 processing (Sowden et al., 2014). However, it is important to note that the final concepts were not particularly complicated or over-elaborated, and typically focused on developing from primary generators found in early *Shaping Ideas*.

While our participants did not explicitly follow deliberate choice tools such as the method developed by Pugh (1981) or the Harris Profile (van Boeijen et al., 2014), they did attempt to systematically work through the problem during convergence, using Type 2 processing (Section 3.3.4). Despite this, these developments were heavily connected to intuitive *Shaping Ideas*, and also highly implicit in their linkage to the rest of the ideation process (Figure 9), suggesting Type 1 processing was also influential during this phase. Across cases, the ideas associated with Type 1 processing turned out to be the same ones that were positively evaluated and eventually selected during the supposedly more deliberate, Type 2 dominated, convergence. Again, this points to an interaction between the two processes, and potential Override Failure, linking our themes together.

5 *Towards a dual-process theory of ideation: mapping novice designers' individual ideation*

Given the strong interactions between our results, we are able to develop a deeper explanation of the observed phenomena rooted in dual-process theory and reflecting a tension and interplay between Type 1 and Type 2 creation and judgement processes. Specifically, we develop two major insights that connect dual-process theory with design research, encapsulated in a proposed Dual-Process Ideation (DPI) model (Figure 10).

We posit that, at each move during ideation, Type 1 and 2 are operating together, continuously linking idea creation and judgment. This understanding forms the basis for our proposed DPI model, as shown in Figure 10. Here, although both types of processing are constant, their relative dominance changes, and it is the alignment in processing between creation and judgment that determines the likely impact of an idea. Particular to our results, and requiring further study, we found evidence for substantial variation in processing during creation (ranging from Type 1 dominated *Shaping Ideas*, to a mixed *Incremental Middle*, and Type 2 dominated *Sacrificial Reframing*) but

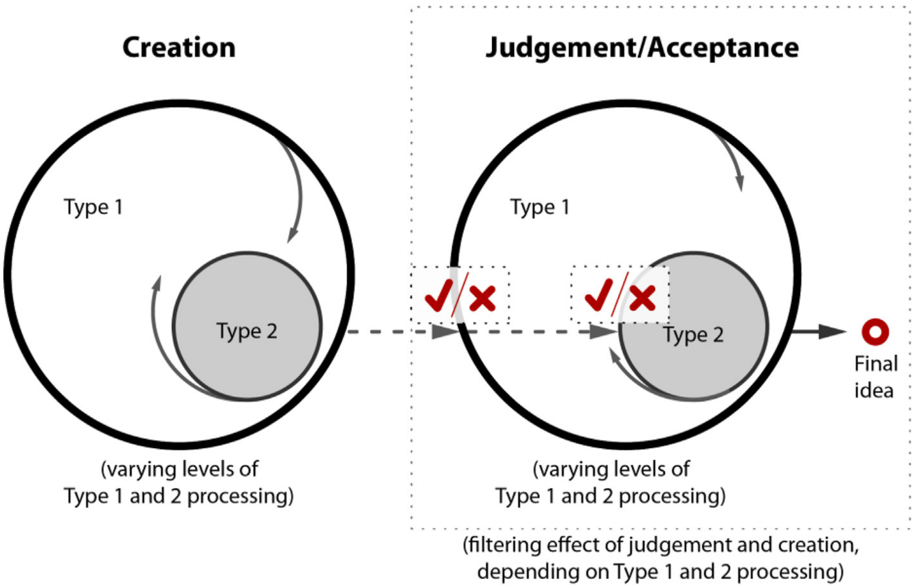


Figure 10 Our proposed generic Dual-Process Ideation (DPI) model linking creation and judgment in ideation

relatively little variation in judgement and acceptance. Figure 11 exemplifies how our results can be explained via the DPI model. Specifically, judgement was consistently dominated by Type 1 processing, which acted as a filter to more deliberate Type 2 judgements. Hence, we suggest that, generally, when creation and judgment both employ similar processing types, for instance, both being driven by Type 1, ideas are accepted and developed. However, when creation and judgement employ substantially different processing types, such as creation being driven by Type 2 and judgement by Type 1 (or *vice versa*), ideas tend to be rejected. There is an apparent preference for Type 1 associations affecting judgement in particular. This can be translated across the four themes as illustrated in Figure 11 and explained below, and resonates well with current understanding of dual-process theory (Evans, 2008; Evans & Stanovich, 2013; Kahneman, 2011), especially regarding accounts of cognitive errors rooted in heuristics and biases (Stanovich et al., 2008).

When generating ideas, Type 1 processing, related to more intuitive associations, is set in motion immediately when the designer first approaches the design problem. This was particularly evident in Theme 1, where *Shaping Ideas*

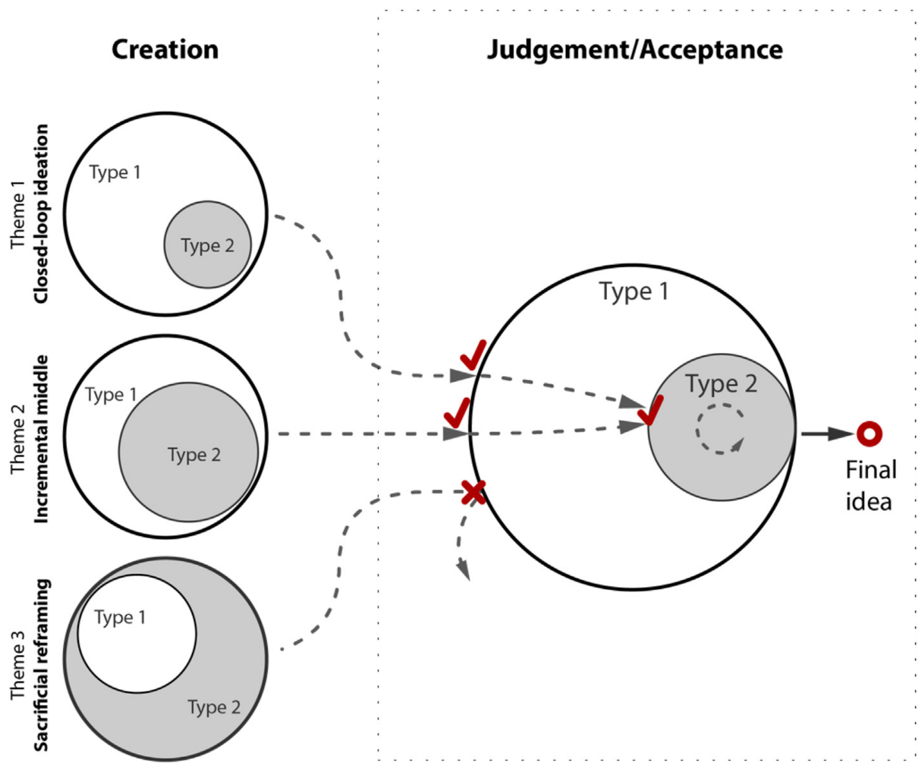


Figure 11 Explanation of our thematic results using the proposed Dual-Process Ideation (DPI) model, illustrating how alignment in dominant processing type between creation and judgement determines idea acceptance and survival

influenced the entire ideation session, resulting in a *Closed-Loop*. During converging stages, Type 1 appears to form a critical filter, substantially influencing what is taken into more analytical Type 2 processing and leading to a high degree of intuitive judgement (Evans, 2003). Even when more deliberate and analytical Type 2 processing is prioritised, ideas that were previously intuitively evaluated positively still tend to be accepted. This is represented in Figures 10 and 11 with the succession of check-marks in red, illustrating how judgement takes place in two stages with Type 1 playing a filtering role.

In relation to Theme 2, characterised by the incremental and deliberate exploration of the problem and solution space, we propose that Type 1 and 2 processing becomes more balanced during creation. In Figure 11, this is represented by a bigger presence of systematic and deliberate processing (Type 2). This Type 2 interaction with Type 1 processing tends to occur when the first burst of early ideas starts to dwindle, leading to a structured exploration of incremental variations on prior solutions or slightly different problem framings. As such, while Type 2 is used in the deliberate exploration, the roots of the ideas are typically closely linked with Type 1 associations. Thus, ideas in the *Incremental Middle* are accepted during judgement as they still follow the core Type 1 associations and thus pass through the Type 1 judgement filter.

Finally, Theme 3 is characterised by deliberate – but ultimately rejected – efforts at reframing, i.e., using Type 2 processing to completely override Type 1 and explore the problem and solution spaces beyond closely related associations. In Figure 11, this is illustrated by a more substantial weight of Type 2 processing in relation to Type 1. *Tangential Ideas* included novel directions that could potentially reframe the whole ideation process, but they were typically immediately and intuitively negatively assessed, and later, not considered for the final concept. As such, their immediate negative judgement driven by Type 1 processing formed a strong filter blocking further Type 2 judgement and potential development. As elaborated in Section 4.4, this particularly refers to the type of reframing we observed in our results, where there was a predominance of Type 2 processing. As such, Type 1-led reframing may follow a different path through our model (Figure 10).

The different alignments between creative and judgemental Type 1 and 2 processing directly explains the observed features of ideation. This can have an immediate impact, in terms of which ideas are externalised (i.e., created) and how much they influence subsequent ideas, due to an instant judgment feedback loop. It can also have a longer-term impact, in how prior ideas are judged during convergence, resulting in ideas able to pass the Type 1 filter being more likely to be combined into a final concept (Theme 4 – *Combinatorial Preference*). This means that the impact of an idea on the ideation process is determined by a continuous interaction between Type 1 and Type 2 processing during creation and judgement. Taken together, this allows us to construct a generic ideation process based on our model, as illustrated in Figure 12. This shows how the general principals of the DPI model (Figure 10) can be used to construct the various idea types and overall process structures observed in our data.

In addition to this explanative power, our model goes beyond prior attempts to link ideation and creativity with dual-process theory. For instance, Guilford's views on divergent and convergent thinking (Guilford, 1950) could be considered analogous to Type 1 and Type 2 processing, respectively. However, despite superficial similarities, direct translation is not possible (Sowden et al., 2014). Divergence can happen to be associative and intuitive, but may also involve deliberate and conscious attempts to expand the design space (Ward, 1994). Similarly, convergence involves both Type 1 and 2 processing. The same could be said about the Geneplore model (Finke et al., 1992). Although having a similar structure to dual-process theory, being composed of two modes of creativity, the Geneplore model does not match descriptions of Type 1 and Type 2 processing (Allen & Thomas, 2011; Sowden et al., 2014). Ultimately our model offers the following testable propositions, which differentiate it from other works in this area:

1. The impact of an idea is determined by the alignment between the processing type at creation and at judgement. Alignment in processing type between creation and judgement will increase acceptance and impact.
2. Ideas created primarily via Type 1 processing will be particularly impactful due to the prominence of Type 1 filtering during judgment.
3. Ideas created deliberately via Type 2 override will be less impactful due to the to the prominence of Type 1 filtering during judgment.
4. Ideas created via a balance between Type 1 and Type 2 processing will particularly shape elaboration and refinement where judgment also balances Type 1 and Type 2 processing.

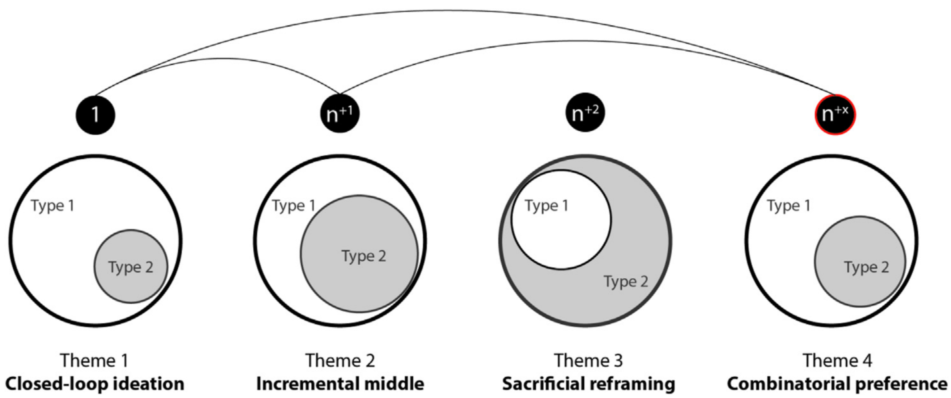


Figure 12 Example of using the Dual-Process Ideation (DPI) model to describe how ideas develop over time

Our model also offers possible explanations for the conflicting results highlighted in the introduction. First, in terms of the dual effect of stimuli, this can be resolved following the alignment explanation illustrated in Figure 11. When designers are focused on Type 1 associations, stimuli closely related to these associations tend to be accepted while more distant stimuli tend to be rejected. In contrast, when designers focus on Type 2 override, more distantly related stimuli tend to be accepted. However, both usages of stimuli would be confronted by Type 1 filtering during judgement and hence have unequal impact on the overall ideation process. Ward's structured imagination theory (1994) and Mednick's associative basis (1962) already point to the relationship between the conceptual cognitive structures one has and the ideas generated. Similarly, Gonçalves et al. (2013) and Fu et al. (2013) have shown that the usefulness or effectiveness of stimuli depends on their relative distance from the design problem, i.e., the cognitive structures of how one understands the problem and stimuli. Our work goes beyond these studies, as it offers an explanation of how stimuli can influence ideation, to a larger or smaller extent, depending on whether there is alignment between Type 1 and 2 processing at moments of creation and judgement.

Second, in terms of the relationship between quantity of ideas generated and the probability of coming to a creative solution, our model decouples quantity and creative impact. In fact, we show how a large number of ideas can be generated and filtered based on Type 1 processing, as well as the simultaneous difficulty in both producing and accepting ideas derived from Type 2 processing. This again goes beyond prior work by Parnes (1961), Basadur and Thompson (1986) and Paulus et al. (2011), who are insightful in describing ideation behaviours, but do not explain the cognitive phenomena at play. In relation to Briggs and Reinig (2007), who have recognised that a number of boundaries influence the rate of ideation, we offer further explanation of their cognitive boundaries. By differentiating between Type 1 and 2 processing, we are able to clarify why the ideation rate decreases over time and why initial ideas have such a far-reaching impact on the later stages of the ideation process.

Finally, in terms of what predicts the uptake of ideas, creative ideas developed via Type 2 override (those referred in this study as *Sacrificial Reframes*) are typically rejected due to the dominance of Type 1 filtering during judgement. On the other hand, Type 1 ideas have a disproportionate impact, even when identified as 'initial thoughts'. This offers an explanation beyond prior work on idea selection, such as the one by Rietzschel et al. (2010) or Starkey et al. (2016). While these authors have clearly shown that original ideas tend to be abandoned for more familiar or feasible ideas, little explanation has been given as to why this occurs. In contrast the DPI model provides an explicit mechanism for this phenomenon.

The DPI model thus provides a promising basis for further study of dual-process based explanations of ideation. However, given the focus of this work has been in qualitative theory development, and in relation to novice designers' ideation processes, further work is required in order to test the specific predictions of our proposed model in contrast to other possible explanations.

5.1 Limitations and future research

Given the theory building nature of this research a number of caveats and limitations should be considered. First, we have focussed on how ideas were created, connected, and judged during a creative process, and not on the quality of the ideas. Although we have observed a strong influence of the first 'gut-reaction' ideas on final concepts, this does not mean that the latter are of low quality. Our study, in fact, could shed light on apparently contradictory results, where it is reported that the best ideas come mostly at the later stages of ideation (e.g., Parnes, 1961; Basadur & Thompson, 1986). Late ideas can perhaps be considered better especially *because* they are built upon early ones and have been extensively combined, elaborated and synthesised. Further work is needed to explore such developmental explanations as well as to conceptualise how type 1 and 2 processing impact the assessment of creative ideas.

Second, our study followed a time-limited and controlled design process, thus further work is needed to evaluate the generalisability of our results for a wider design practice. Future research should pay attention to a complete mapping of the idea archetypes, considering that the eight found here may not reflect an exhaustive set of all possible permutations. Nevertheless, our proposed model (Figure 10) allows for a generic theoretical framework for further exploration of idea archetypes and process in practice. Furthermore, one of the major themes we have emphasised is the *Combinatorial Preference* (Theme 4), which showed a heavy influence of the first ideas on the final concept. It would be relevant to further investigate whether the combinatorial ideas archetypes would be as prevalent in longer design projects. Another point that deserves further attention is whether other alternative explanations are responsible for *combinatorial preferences*, such as training or task expectations. Similarly, we have controlled certain parameters, such as the use of stimuli, and thus further work is needed to explore other variables, such as brief open-endedness, constraints, designer expertise, designers' background, and group dynamics. In particular, individual student participants are ideal for increasing internal validity and supporting theory building, as in this work (Druckman & Kam, 2011; Henry, 2008), but require further study of the wider population and other settings (including experts and group contexts) to understand external validity. Despite this, our results consistently align with descriptions in the literature and hence provide a basis for such investigation.

Finally, it is important to reiterate that the empirical analysis of the two processing types (Type 1 and Type 2) is always an approximation. In order to differentiate Type 1 and 2 processing, we have analysed the implicit and explicit links between ideas, following prior literature in this area (Cash & Kreye, 2018; Sloman, 1996, 2002). As such, while the approach used in this research is well-accepted for differentiating the two types of processing in protocol data, further work is needed to examine its robustness in comparison to alternative measures, such as biometrics (Sowden et al., 2014).

6 Conclusion

This study set out to better understand the creation and evolution of ideas over time, individually and as a whole, with the aim to resolve conflicting accounts of ideation. We have done this by carrying out a protocol and network analysis with 31 designers, who have created ideas and a final concept to answer a design brief in individual ideation sessions of 40 min. Based on our findings we have proposed the *Dual-Process Ideation (DPI) model* (Figure 10).

The DPI model offers potential explanations for major conflicting results in the design creativity literature, forms the basis for a consistent explanation of idea creation, development, and judgement, and provides propositions for future testing. As such, this research has three main contributions.

First, the DPI model distinguishes ideas in two dimensions: idea creation (the circumstances involving its emergence) and idea judgement (the circumstances surrounding its appraisal, which can lead to the idea being selected, modified, combined or even abandoned). Together, these dimensions account for two essential stages of the life cycle of creative ideas. This conceptualisation of ideas dissolves previously conflicting descriptions and serves to link the definition of ideas to an understanding of ideation rooted in dual-process cognition.

Second, the DPI model allowed us to explain both archetypal ideas as well as ideation process structures. Specifically, we identify and explain eight idea archetypes that emerged from this study: *Shaping, Incremental, Tangent, Bridging-Balanced, Bridging-Foresight, Bridging-Hindsight, Combinatorial*, and *Final Combinatorial*, and four process structures: *Closed-loop Ideation*, *Incremental Middle*, *Sacrificial Reframing*, and *Combinatorial Preference*. Although further research needs to ascertain whether these archetypes cover a full range of ideas, these eight allow us to start disambiguating prior research by more clearly differentiate ideas across the ideation process, and providing an explanation that relates the definition of an idea and the progression of the ideation processes.

Finally, the DPI model explains ideation in terms of Type 1 and 2 processing continuously linking idea creation and judgment. Here, it is the alignment in types of processing at creation and judgment that shapes the impact of an idea. This serves to integrate design *process*-based and *cognition*-based accounts of ideation and provides testable propositions for future ideation research.

This study has potentially important implications for design education and practice. Being aware of the cognitive tendencies that might impact the ideation process can lead to the development of strategies to better cope with limitations to ideation (such as the dual effect of stimuli or idea selection). In this regard, design educators can have a crucial role in guiding novice designers in reflecting and becoming aware of their ideation, both at a process level as well as cognitively. However, as with all new theoretical developments, further work is needed to expand, test, and elaborate the DPI model. Thus, this work takes the first steps towards a Dual-process Theory of Ideation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Notes

1. Industrial Design Engineering Faculty, Delft University of Technology, 2628 CE, Delft, the Netherlands.

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