Sticky Notes as a Kind of Design Material: How Sticky Notes Support Design Cognition and Design Collaboration

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Abstract: Sticky notes abound as a material in design practice, yet their use is under-explored empirically and theoretically. We address the research question: *how* do sticky notes support design cognition and collaboration when compared to other kinds of design materials? We compare four types of design materials (sketches, prototypes, cards, sticky notes) and the activities afforded by the properties of these materials. We find that the affordances of sticky notes make them well-suited to supporting cognitive processes associated with visualizing and understanding "part/whole" relationships in concept development. Furthermore, sticky notes facilitate design collaboration by enabling shared attention through material anchors and the modulation of turn-taking. We conclude by suggesting new directions for theorizing about sticky-note usage in design.

Keywords: Design practice, design cognition, collaborative design, affordance, design material

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Sticky notes abound as a material in design practice, yet their use is under-explored, both empirically and theoretically. The extant literature indicates that minimal theorising has attempted to link sticky-note usage to creative processes in general or design processes in particular, with the few notable exceptions relating to articles appearing in the recent edited collections by Christensen et al. (2017, 2020a)[1]. Part of the reason for this lack of investigation and conceptual analysis of sticky-note usage may relate to the sheer ubiquity and apparent simplicity of this design material, seemingly rendering sticky notes mundane, inconsequential and lacking merit as a serious focus for research. We argue here, however, that to disregard the humble sticky note as a key support material in creative design is to ignore a whole sphere of cognition that underpins effective real-world design practice that is central to contemporary human achievement and ongoing technological advancement.

Sticky notes are probably the most utilized of all design materials in contemporary, professional contexts in which the generation, exploration and evaluation of creative ideas is paramount (Harboe & Huang, 2015). For example, the technique of "brainstorming", originally developed by Osborn (1953) and frequently used a design technique by experts and novices (Gonçalves et al., 2014), is typically carried out with sticky notes (Firestien, 1996; Straker, 2009). Indeed, Tim Brown, the CEO of IDEO, goes as far as to argue that sticky notes are the perfect material for brainstorming, providing a way for team members to converge on a solution when many possibilities exist (Brown, 2009). The methodology of "Creative Problem Solving" (e.g., Treffinger et al., 2005) likewise builds upon brainstorming, with sticky notes being used to support both divergent and convergent thinking.

Sticky notes are mainly hailed as a visual support material for situated collaborative design. The list of sticky-note methods related to collaborative design activities is very long and growing, as evidenced by the dozens of design techniques using sticky notes described in popular design-methods handbooks (e.g., Hanington & Martin, 2012; Kumar, 2012; Tomitsch, 2018). Beyond brainstorming, sticky-note techniques also include affinity diagrams (e.g., Beyer & Holzblatt, 1998), mindmaps (e.g., Kokotovich, 2008), card sorting (e.g., Hanington & Martin, 2012), story boarding (e.g., Buxton, 2010;

[1] Christensen et al. (2017) is a set of papers deriving from the Eleventh Design Thinking Research Symposium (DTRS11), which revolved around the analysis of team design activity in which sticky notes featured as a core design material. Selected chapters from Christensen et al. (2017) were revised and developed through peer review and subsequently published in two journal special issues, respectively edited by Ball and Christensen (2018) and Halskov and Christensen (2018). Christensen et al. (2020a) is an edited book covering sticky note cognition, technology, and design processes.

Sibbet, 2010; MacKay, 2020), user empathy maps (e.g., Tschimmel, 2012), combinatorial creativity (e.g., Michalko, 2010), decomposition and abstraction (Firestien, 1996) and future workshops (Kensing & Madsen, 1991). Sticky notes are also utilized for information management by designers (Bernstein et al., 2008; Fischel & Halskov, 2018, 2020). Although sticky notes come in pads and were originally intended as bookmarks to re-find information in layered documents (e.g., books), their life in design collaboration usually takes place without layering, where they are used to populate a shared visual design space such as a whiteboard or other flat worksurface ("notes-on-boards").

In terms of their extensive use in professional creative practice, sticky notes have clearly come a long way since their original invention and release into the US market by 3M in 1980, appearing as Post-it® notes in their signature canary yellow. By the mid-1990s sticky notes were among the bestselling office products in the world. It is hard to imagine today that the Post-it® note was not originally intended for extensive use in creative collaboration or as a visual design material but was rather marketed with the more limited vision of it being a bookmark that could be annotated. It was not, however, until the early1990s that the use of sticky notes can be consistently linked to methods that underpin creative innovation and collaboration such as brainstorming, affinity diagramming, mindmapping and participatory design, which all nowadays reflect the predominant ways in which sticky notes are used in professional contexts (Lavenda, 2014).

With the benefit of hindsight, it is apparent that when sticky notes first arrived on the scene they immediately satisfied a universal need for a highly versatile design material that can be used for many different purposes in different contexts, not least to facilitate acts of design and innovation. Although sticky notes are an excellent design material to support invention, innovation and design it is also important to appreciate the caveat that the emergence of sticky notes did not in itself have a direct causal influence in engendering *new* methods for collaborative creativity (Christensen et al., 2020b). Creativity techniques such as the "stick-em-up" version of brainstorming that makes use of sticky notes could be carried out with other materials, and the brainstorming method itself (e.g., Osborn, 1953) pre-dates the development of sticky notes. That said, sticky notes certainly make brainstorming a more seamless and effective process as team members can simultaneously write down their own ideas, which can then readily be shared, augmented and manipulated in a common workspace.

The use of sticky notes has also benefited the increasing inclusion of prospective end-users and consumers in collaborative design activity, supporting a marked growth over the past 30 years in

participatory design and co-design. Participatory design is championed as a *democratic* approach that creates contexts to support mutual learning, thereby ensuring that end-users and non-designers have a voice in the design process (Christensen et al., 2020b; Robertson & Simonsen, 2012). Furthermore, this mutuality between users and designers is typically facilitated through the deployment of "low-tech, non-specialized design materials that any person can intuitively pick up and utilize to make a creative contribution, making the sticky note an obvious first choice" (Christensen et al., 2020b, p. 5; see also Suthers & Hundhausen, 2003, for how low-tech materials are frequently used by designers and managers).

In the present conceptual position paper, we aim to address a research question regarding sticky notes that is of considerable theoretical and practical importance: *how* do sticky notes support design cognition and design collaboration when compared to other kinds of design materials? To address this question, we first consider the importance of "design materials" in design activity, exploring the critical roles of sketches, prototypes and card-based resources, before examining the role of sticky notes. We then perform an analysis in which we focus on the many cognitive and collaborative activities that are afforded (Gibson, 1979) by the core physical properties of sticky notes (i.e., paper, size, shape, color and stickiness) and the types of representation they allow for. We identify affordances of sticky notes (e.g., they are relational, re-configurable, categorizable and the like) that make them highly suited to specific aspects of design cognition associated with "part/whole relationships", which we elaborate upon in the subsequent section. We then move on to explore how sticky notes support design collaboration, and how *digital* sticky notes may differentially afford specific types of interaction and cognition when compared to their physical counterpart. We conclude by suggesting new directions for research on sticky-note usage in design.

1 The importance of design materials

The activity of designing is replete with the use of design materials that support the externalization, exploration, manipulation and development of ideas and concepts. The extensive use of sticky notes seems to suggest that they may be a special kind of design material that perhaps supports design cognition and collaborative interaction differently from other highly studied design materials (e.g., sketches, prototypes and card-based resources). To explore how sticky notes provide support for design cognition and collaboration we initially discuss how design materials serve as "preinventive structures" (Finke et al., 1992), possessing certain properties that are especially conducive to *creative design*. However, different types of design materials do not support design

cognition and collaboration in exactly the same way or with the same effects, so in subsequent sections we reflect on how sketches, prototypes and card-based resources each link to design cognition and collaboration in separable ways. While sketches, prototypes and card-based resources partly overlap in terms of their usage, we focus below on trying to tease them apart to explicate their somewhat distinct ways of supporting design cognition and collaboration. We then turn to how sticky notes compare to, and contrast with, these other kinds of design materials.

In the present context, we use the term "design material" in a generic sense to refer to the combination of the physical properties of the material (e.g., paper, card, plastic) and the kinds of representation that the material allows for (e.g., sketches, drawings, text, working models). Importantly, we are not interested in the static or passive properties of design materials per se, but rather in how the dynamics of materials-in-use differentially affect cognition and collaboration in creative design practice. By referring to sticky notes as a "design material" (as opposed to as a "tool" or a "medium")[2] we highlight the types of socio-material interaction and cognition they allow for (i.e., the types of thinking they afford and the types of collaborative design activities they support). Our following analysis therefore aims to uncover how sticky notes compare to, and potentially stand out from, other types of design materials.

One of the most commonplace and central design materials is the paper-based sketch (Lawson, 2004), which appears to be vital not only for facilitating the communication of ideas between team members and other stakeholders but also for the formation and transformation of ideas (cf. Dix & Gongora, 2011). While sketching is often employed at the early, conceptual stages of design, another type of material support, namely prototyping, is typically applied in later detailing stages of the design process. According to Sanders and Stappers (2014), prototyping is of value both during the production of design ideas and insights as well as during their formative evaluation. Yet another common type of design material takes the form of card-based design resources (e.g., Roy & Warren, 2019; Wölfel & Merritt, 2013) that are used mainly during the early stages of the design process and involve textual as well as graphical cards that designers can place and manipulate so as to cue associations and ideas. In the literature on design materials, however, sticky notes have not received much attention. For the present purposes, sketches, prototypes and cards will serve as the central points of comparison to

[2] We choose to avoid the term "tool" to describe design materials, unless the materials are associated with specific, prescribed procedures for their application. We also choose not to use the term "medium", as this is often used when referring to the *capturing* of representations of externalized thought, thereby placing an emphasis on externalized outcomes. In the present context, the main point is not that sticky notes can capture representations, but rather that they may allow for certain types of design cognition and collaboration.

sticky notes in order to understand how sticky notes may support design cognition and collaboration differentially or in a similar manner to the other design materials.

From the perspective of theorising about the nature of creative cognition, design materials can be viewed as "preinventive structures" (Finke et al., 1992), which represent fragmentary solution ideas that can promote creative discovery and eventual progress toward full-blown creative solutions for current problems. Although Finke et al.'s (1992) notion of preinventive structures is primarily focused on internal "mental" representations, they also acknowledge that "there is no reason that the structures could not be externalized at any point in the creative act" (Finke et al., 1992, p. 23). As they note, one advantage of externalization is that the creator can deal with more complex structures than would be possible purely in imagination. Importantly, as Finke et al. (1992) explain, the critical element of all preinventive structures is that they are initially produced without full anticipation of their resulting meaning and interpretation. In this way, preinventive structures should be viewed as distinct from finalized creative products.

Preinventive structures are viewed by Finke et al. (1992) as possessing six inter-dependent properties that can afford creative outcomes through exploration and discovery. These properties relate to: (i) *novelty*, with greater novelty affording greater possibilities for creative discovery; (ii) *ambiguity*, which provides opportunities for creative interpretation; (iii) *implicit meaningfulness*, which serves to inspire new and unexpected interpretations; (iv) *emergence*, which engenders unanticipated attributes and relations; (v) *incongruity*, which involves conflict or contrast that can encourage exploration to expose deeper meanings and relations; and (vi) *divergence*, which relates to the capacity to facilitate the discovery of alternative uses, meanings and interpretations.

Although most design materials share these pre-inventive properties, this does not mean that they all provide support for design cognition and collaboration in the same way. Indeed, the choice and use of design materials impacts in important ways on design cognition and design collaboration and the nature of these different influences will occupy us in the present paper. For example, Christensen and Schunn (2007) showed how the presence of sketches or prototypes versus the absence of design material in a design team significantly affected design dialogue pertaining to the team's use of analogical reasoning.

One important distinction between design materials pertains to representational form (e.g., visual, textual). When it comes to designers looking for inspiration from external sources, they self-report a strong preference for visual information over other information formats (Gonçalves et al.,

2014). There is, indeed, evidence for the efficacy of visual sources of inspiration in design (Christensen & Schunn, 2009), with Casakin (2005) having shown that a rich collection of pictorial representations can help architects when dealing with ill-defined problems. Other studies, however, have indicated that the use of visual representations of possible design solutions can hinder the subsequent generation of potentially superior design ideas because designers "fixate" on the properties of the initial representations (Jansson & Smith, 1991; Perttula & Liikkanen, 2006; Purcell & Gero, 1996). Although the advantages of visual stimuli for inspiring creative idea generation in design remain unclear because of contradictory findings, other evidence has suggested that text-based stimulus formats might also have certain benefits. For example, Goldschmidt and Sever (2010) demonstrated a positive influence on the originality of students' design solutions as a function of them receiving text-based stimuli during idea generation in comparison to a condition in which no external stimuli were presented.

Design materials also play important roles in collaborative design processes. They may be viewed as "material anchors" (Hutchins, 2005), that is, externalizations that can give a degree of stability to a conceptual representation to facilitate further exploration and reasoning in design teams. The deployment of design materials in co-design processes may necessitate varying degrees of design expertise or skill; the materials may invite collaborative efforts versus individual design activities and the social interaction involved may be more or less socially scripted.

Below, we first briefly review the literature covering the use of sketches, prototypes and card-based resources in design, as the deployment of these materials can provide insights into how sticky notes are (dis)similar to other important design materials, and how they might help support design cognition and collaboration in (dis)similar ways.

1.1 Sketches

Design seems unimaginable without the production of sketches and drawings on paper, with extensive evidence indicating that these are produced during several stages of the design process, serving many different purposes such as supporting idea generation (Atilola et al., 2016; Van der Lugt, 2005), creative discovery (Purcell & Gero, 1998; Suwa & Tversky, 1997; Verstijnen et al., 1998), shape transformation (Prats et al., 2009) and idea evaluation (Kavakli et al., 1998). Designers often emphasize the utility of freehand drawings and rough sketches produced during early design stages, especially delighting in their vagueness, incompleteness, uncertainty and ambiguity. Indeed, it is the latter properties of these external visualizations that appear to serve such an important function

as a catalyst for creative thinking (Fish & Scrivener, 1990; Goel, 1995; Scrivener, 1982; Scrivener et al., 2000; Tversky & Suwa, 2009).

As noted by Schön and Wiggins (1992), the inherent properties of sketches support iterative processes of "seeing-moving-seeing" that take the form a continuous "conversation" between the designer and the sketch that transitions back and forth between doing and appreciation. In a similar vein, Goldschmidt (1991, 1994) proposes that design thinking that arises in the context of sketching activity can be viewed as a dialectic between two different forms of seeing, that is, "seeing-as" and "seeing-that", with shifts between these two forms of seeing serving to stimulate new ideas through creative reinterpretation. Lawson (2004) studied architectural and design sketches, and distinguished between proposition drawings and diagrammatic drawings, with the latter containing few physical or visual qualities of real object, while still allowing relationships to be expressed precisely. Professional design sketching requires years of skill acquisition in the design studio and is typically conducted as an individual activity, although collaborative sketching is also possible.

1.2 Prototypes

Prototypes are commonplace in design and are "representative and manifested forms of design ideas" (Lim et al., 2008, p. 10). Although prototypes are important as a means to evaluate the efficacy of design ideas (e.g., Floyd, 1984), they have much greater utility beyond this evaluation function, also enabling design thinking and reflection throughout the design process, thereby facilitating idea generation, discovery and refinement. Indeed, Deininger et al. (2017) emphasize how prototypes are often one of the best visual and tangible ways of communicating ideas during the early phases of design that are characterized by processes of problem definition and ideation. In key respects, prototypes appear to operate in much the same way as sketches, which makes it perhaps unsurprising that many design prototyping approaches also capitalize upon sketching techniques (e.g., Bailey et al. 2001; Segura et al., 2012).

The value of prototypes in design has been supported by Youmans (2011), who provides evidence that prototyping can have beneficial effects in reducing designers' tendencies to fixate on prior examples of solution ideas, leading to better and more innovative designs. Prototyping has also long been popular in participatory design as a way to understand user needs and values by actively engaging users in creating and exploring design ideas (Hillgren et al., 2011; Molapo & Marsden, 2013). Research exploring the experience of designers whilst using low-fidelity prototypes has

revealed that the rapid visualization of multiple ideas allows practitioners to reframe failures as opportunities for learning, thereby facilitating a sense of progress (Gerber & Carroll, 2012).

In providing a rigorous analysis of the nature of prototypes in design, Lim et al. (2008) propose an "anatomy" of prototypes based around the two dimensions of "filtering" and "manifestation", which they argue align with the two primary functions of prototypes. The filtering dimension corresponds to the various aspects of a design idea that a designer tries to represent in a prototype, which they also need to consider during the design idea's subsequent exploration and refinement. As such, the filtering dimensions of a prototype may capture its appearance (e.g., size, color and shape), its data (e.g., size, type and organisation), its functionality (e.g., whether it is system-oriented or user-oriented), its interactivity (e.g., inputs, outputs and behaviours) and its spatial structure (e.g., 2D vs. 3D; tangible vs. intangible vs. mixed-interface elements). The manifestation dimension, on the other hand, captures three core aspects of the manifested forms of a prototype in terms of its materials (e.g., paper, wood or computational), its resolution (i.e., the level of detail or sophistication of what is manifested, which corresponds to a prototype's "fidelity") and its scope (i.e., whether it covers only one aspect of a design idea or several aspects of a design idea).

Design approaches based around the collaborative construction of prototypes continue to burgeon, fueled by developments in additive manufacturing (i.e., 3D printing), which enables the fast fabrication of physical parts, models or assemblies using computer-aided design in a process referred to as "rapid prototyping" (Sass & Oxman, 2006). The making of prototypes has also spilled out from the domain of design to become a core element of creative thinking in fields such as entrepreneurship (see Brown, 2009, on "design thinking"), management (e.g., Liedtka & Ogilvie, 2011) and business innovation (for developments in "serious play" see Schrage, 1999; for developments in "experimentation" see Felin et al., 2019, and Thomke, 2003).

1.3 Card-based resources

Card-based resources are commonly deployed during the early, ideation stages of design, but they can also support later phases, including ongoing concept development and the evaluation of design concepts (Lucero et al., 2016). These materials involve the use of either textual or graphical cards that usually have semi-structured, predefined content, with the cards being used to evoke associations and ideas. Card-decks are characterized by being simple, tangible and easy to manipulate, and are widely used by designers to make the design process visible and less abstract,

thereby supporting communication between members of the design team and users (Wölfel & Merritt, 2013).

Typical examples of card-based materials are "Playful Experiences (PLEX) Cards", and "Inspiration Card Workshops". PLEX Cards (e.g., Lucero & Arrasvuori, 2010, 2013) support designers' *playfulness* when designing and evaluating interactive products and services. They involve a deck of 22 cards, with the top-half of each card visually depicting and labelling a different human emotion or experience (e.g., discovery) in an abstract way and with the bottom-half showing a concrete example from everyday life. PLEX Cards can be used individually or by teams in a variety of systematic, rule-based ways (albeit with elements of chance arising from random card-selection) to support problem understanding, idea generation and the development of use scenarios. Inspiration Card Workshops (Halskov & Dalsgaard, 2006) are design events involving designers and collaborators working to co-create design concepts. Inspiration Cards comprise a picture, a title and optionally a short text snippet and are either "Technology Cards" or "Domain Cards". Inspiration Card Workshops involve designers collaboratively combining cards and placing them on posters to generate and document novel, emerging design concepts. There are no set rules for turn-taking or card combination, enabling an open and free-flowing ideation process.

In the most comprehensive review to date, Roy and Warren (2019) examined 155 card-based tools, including a recent upsurge in newly developed card-decks both for general creative thinking as well as for supporting human-centered design. They found that card-decks: (i) facilitate creative combinations of information and ideas; (ii) provide a common basis for understanding and communication in a team; (iii) provide tangible external representations of design elements or information; (iv) deliver convenient summaries of useful information; and (v) exist as semi-structured tools somewhere in between a blank sticky note and detailed instruction manuals. The largest proportion of available card-decks are aimed at facilitating creative problem solving, followed by tools for domain-specific design and for human-centered design.

In discussing why design cards seem to work so well as collaborative design materials, Lucero et al. (2016) note three common characteristics: they are "tangible idea containers", serving to anchor discussions and debates and to enable ideas to be carried forward over time; they act as triggers for "combinatorial creativity" allowing concepts from different domains to be brought together meaningfully to form novel concepts; and they are "collaboration enablers" that facilitate mutual

access and joint ideation by virtue, for example, of being moveable, relocatable, juxtaposable, annotatable and shareable.

2 Sticky notes as a design material

As a design material, sticky notes share their central preinventive properties (i.e., novelty, ambiguity, implicit meaningfulness, emergence, incongruity and divergence) with sketches, prototypes and card-based resources, which goes a long way towards explaining their value in design. Yet, the activities carried out with sticky notes in design differ in important ways from the other types of design materials. This suggests the need to dive into the details of *how* the different properties of design materials engender design activities in order to understand more fully how they support design cognition and collaboration. Below, we first explore some of the affordances of sticky notes, and then compare them to other design materials.

2.1 The affordances of sticky notes

The physical properties of a sticky note are quick and easy to list, that is, a sticky note is a small, tangible, cheap, rectangular, lightweight, flexible and intuitive material for capturing any type of written or visual content, including words, concepts, sketches and models. It has a trademark small strip of reusable adhesive on the reverse, making it fixable, removable, and refixable to certain surfaces (Ball & Christensen, 2020, p. 21). We draw upon five physical properties of sticky notes as described by Christensen et al. (2020b) and reflect here on how the properties of paper, size, shape, color and stickiness relate to design activities.

Despite many predictions to the contrary, offices are still heavily dependent on paper in a digital age (Sellen & Harper, 2003), likely due to important affordances of paper that are not easily transferred to a digital context. As a lightweight and flexible material, paper is readily spread out on work surfaces or hung on walls or boards, and invites “free-form annotation”, whether written or drawn. Paper is also tangible and physical and therefore shareable (DiGiano et al., 2006), making it well suited for co-located, collaborative activities. Finally, paper is an ephemeral material, rendering it useful for the rich, dynamic and situated support of ongoing thinking and conceptual work. Although the properties of paper help explain how it can support collaborative design work in general, we stress the importance of examining the other central properties of sticky notes to understand further why they can, in particular, benefit collaborative, creative activity in contexts such as design.

In terms of size and shape, sticky notes are *small* and *rectangular*, with this small form-factor enabling the writing of just "mere snippets of ideas, aspects or single concepts that somehow relate to the problem context or design issue at hand without necessarily being meaningful in isolation" (Christensen et al., 2020b, p. 7). Typically, only a few words are entered on each note, with one study revealing that each note contained 3.8 words on average, with the most frequent entry being a single word, which was typically a noun (Christensen & Friis-Olivarius, 2020). By writing ideas and aspects of ideas on separate notes, the design space becomes parsed into visually distinct units, which may serve important functions in relating parts to wholes and in providing material anchors in support of team dialogue. The small form-factor means that sticky notes can be used quickly, easily and informally to generate many potentially relevant – albeit somewhat disconnected – ideas without designers needing to possess full insight into where the generated information might be leading. In a short amount of time a blank workspace can thus become populated with a multitude of visually distinct ideas.

Visual parsing and material anchors are especially important in the early stages of design, as initial ideas can be difficult to articulate precisely to others, making it challenging to converge on a shared team understanding in collaborative contexts (Stigliani & Ravasi, 2018). In such situations, gesture and gaze become important resources to establish dialogue (Christensen & Abildgaard, this issue). The informal idea generation arising with sticky notes may be carried out without much specialized training in support of the kind of democratic, end-user engagement that is vital in participatory design contexts (Robertson & Simonson, 2012; Halskov & Hansen, 2015). Indeed, the relatively uniform size of sticky notes can itself be viewed as an "equalising" factor, which serves to mitigate the possibility of one person's ideas outshining another's by virtue of the context of representation.

With respect to color, the original and iconic canary yellow of sticky notes is nowadays supplemented by a large variety of other sticky-note colors. The availability of such colors immediately invites the color-coding of creative outputs, for example, to demarcate conceptually distinct design entities, content types or activities (Fischel & Halskov, 2020), or to trace of authorship (Christensen et al., 2020b). In terms of stickiness, the trademark adhesive strip on sticky notes easily allows them to be affixed, removed and reaffixed to the workspace (e.g., table, wall, window, board, whiteboard). With respect to the most typical sticky-note context (i.e., blocks of sticky notes and an available whiteboard), the "moveable" quality of sticky notes makes for rich possibilities in relating individual notes to each other (Christensen & Abildgaard, this issue) by conceptually combining

notes, grouping notes (Dove et el., 2018) and structuring several notes in conceptual models. The not-so-sticky quality of sticky notes also makes them suitable as temporary annotation devices, including meta-informatic annotation, where they annotate other representations.

2.2 Comparing sticky notes to other design materials

We propose that the properties of sticky notes as a design material differentially afford (relative to other design materials) a set of distinct design activities. Table 1 provides a summary overview of the different types of design materials that we have discussed and how they respectively afford the key design activities of idea generation and conceptual design. Admittedly, the brief descriptors for each design material do not do full justice to the rich set of activities that can be performed with them. But for the present purposes, the descriptors may suffice to bring out some of the key similarities and differences between the four kinds of design materials. The table illustrates how sticky notes as a design material afford a set of activities that other design materials also support, whilst also offering relatively unique affordances for activities that are not readily supported by the other materials.

Sticky notes and sketches share the obvious quality that they are paper-based design materials offering, respectively, a blank note or a blank page to begin with, which flexibly allows for the subsequent instantiation of any type of written or drawn representation. Both materials may thus be used for sketching, albeit sticky-note sketches are somewhat limited by their form-factor. Interestingly, diagrammatic drawings (e.g., mindmaps) as a form of sketching are often used in conceptual design, which involves establishing structural relationships between elements (Lawson, 2004). The same type of activity may also be performed with sticky notes, but here elements are parsed onto individual sticky notes, with relations typically drawn between notes on the whiteboard. Sticky notes and sketches differ in their typical uses, with architectural sketching being mainly a non-scripted, individual activity that requires a high degree of expertise, taking years to master. Sticky notes, on the other hand, can be used by anyone because of their small form-factor and their intuitive interaction affordances.

Table 1. Descriptions of design materials (sketches, prototypes, cards and sticky notes), including their uses and their affordances across creative design activities

	Sketches	**Prototypes**	**Cards**	**Sticky Notes**
Material				
Material representation	Sketch Drawing Occasional textual annotation	Physical Computational	Text Images	Text Sketch Drawing
Modality	Visual	Cross-modal Multi-sensory	Visual	Visual
Initial content	Blank page	Rich, unstructured set of available materials	Rich, semi-structured content	Blank note
Use				
Expertise level	Takes skill to master	Takes skill to master	Easy to use	Easy to use
Scripted interaction	Non-scripted	Non-scripted	Scripted	Scripted or non-scripted
Co-design	Individual	Individual or collaborative	Collaborative	Collaborative
Affordances Across Creative Design Activities				
Idea generation	Free-form sketching Fabulous drawing	Tinkering Experimenting	Bringing in information Playing	Writing Populating a workspace with multiple parts Sketching
Conceptual design	Drawing diagrams Structuring	Decomposing Configuring Building Combining	Moving Sorting Relating Combining	Moving Sorting Relating Combining Arrange in diagrams Structuring Decomposing Re-configuring Building

The parallels between card-based materials and sticky notes are readily apparent given the similarities in their shape, size and tangible nature, albeit with most card-based design methods relying on pre-established content. The most significant difference between the two materials is the fact that sticky notes are initially blank, whereas cards initially contain rich content in terms of images and/or text. Some of the card-based design methods are more scripted than the usage of sticky notes, for instance, in terms of separate phases for presenting and for combining cards, or rules for turn-taking in card-based design games. Some of the key activities afforded by both cards and sticky notes concern the combining, relating, moving and sorting of objects in conceptual design.

At first glance there appear to be few similarities between sticky notes and prototypes, with physical prototyping being typically based on skillful construction and *tinkering* using a rich set of available materials beyond paper. However, it is noteworthy that there is some overlap in the affordances of these two design materials for conceptual design, where both sticky notes and prototypes involve the dynamic combining, decomposing, configuring and building of concepts.

Looking across the comparisons between sticky notes and the other types of design materials, there are few affordances that are unique to sticky notes. What does seem evident, however, is that the "notes-on-boards" implementation of sticky notes is particularly well focused on visual support for what may be termed "part/whole" relations in conceptual design. Again, support for part/whole relations is not the sole preserve of sticky notes, and the structural relating of whole concepts to their individual components or parts may also be carried out with other design materials. For example, diagrammatic drawings can help to make explicit the structural relations amongst elements (e.g., in mindmaps). Only in the sticky-note version, however, do such diagrams become dynamic, with *movable* parts. In card-based methods, the moving of cards relative to other cards allows for comparisons and juxtapositions, whereas in prototyping, parts are dynamically combined to create new emergent wholes and can also be decomposed into their individual elements. However, none of the other materials seems to afford the full range of part/whole operations (e.g., moving, combining, sorting, decomposing, building, structuring) as easily, intuitively and dynamically as sticky notes do. With individual sticky-note content representing parts, and with interlinked sticky notes representing wholes (e.g., note-clusters, note-networks or note-based model structures), it becomes highly intuitive for sticky notes to support visually the development of complete design concepts.

The ubiquitous, simplistic and democratic nature of sticky notes has perhaps meant that they have been somewhat overlooked in the design literature, which most often has focused on materials

requiring more extensive expertise to master, including prototypes and sketches. Further, the tight coupling of sticky notes to highly scripted, user-centric design methods stemming from IDEO has perhaps led to the perception that the methods performed with sticky notes might be too constrained to afford open-ended expert design behavior involving ill-defined or "wicked" problems of the type that characterize professional design. We contend, however, that the ubiquitous, simplistic, democratic and generic nature of sticky notes in design are *virtues* that attest to their importance as a design material whilst also speaking to the need to engage in a penetrating conceptual analysis of their usage so as to understand how they support design cognition and collaboration.

3 The specific capacity for sticky notes to support part/whole design cognition

Several design theorists have highlighted the importance of designers working back and forth between detailed design elements and whole concepts (e.g., Alexander et al., 1987; Nelson & Stolterman, 2003; Schön, 1983; Wiberg, 2014). In examining the nature of sticky notes in the previous section we have proposed that they are especially useful for affording the visual display and dynamic relatability of "parts" to conceptual "wholes" in support of design cognition. We now consider further how part/whole relationships have been argued to support cognition for other types of design materials as doing so can provide deeper insights into how sticky notes might also be supporting design cognition.

First, in relation to sketches and drawings, we note that diagrammatic representations have been claimed to possess certain properties that give them an advantage over other representations to support scientific discovery and creative invention, for example, by reducing the amount of computation required to search for and recognize information (Cheng & Simon, 1995). One main reason for this capacity resides in diagrams explicitly preserving information about the topological and geometric relations amongst the parts of a problem or concept, which the sentential structure in natural-language descriptions is ill-equipped to achieve (Larkin & Simon, 1987). This means that the proximity of parts and their relative positioning on visual displays become meaningful sources of information for the problem solver (Wickens & Carswell, 1995). Indeed, Larkin (1989) has argued that in so-called "display-based problem solving", very little information needs to be held in working memory, once externalized. Second, turning to card-based materials, these have been argued to support the generation of ideas through association with content information and through conceptual combination involving the relational movement of cards (Roy & Warren, 2019). Third, the playful tinkering and experimentation associated with prototyping speaks to its capacity to support the

discovery of emergent system properties through dynamically interrelating parts into new wholes (Lim et al., 2008; Schrage, 1999).

Based on these aforementioned insights, how, then, do sticky notes support design cognition in terms of part/whole representations and attendant reasoning processes? We contend that because sticky notes can visually display both individual parts in design and the conceptual relations amongst these parts in forming wholes, then it becomes possible for designers: (i) to consider the parts as "variables" in a system, thereby enabling the exchange of parts, while retaining the structural whole; (ii) to restructure the whole representation into new representations by re-configuring the parts; and (iii) to explore and establish dynamically new possible structural links to existing concepts, thereby gradually and generatively "building-up" or advancing a conceptual whole with new emergent properties.

In the course of the design process, parts and wholes become established and interconnected through the application of several distinct cognitive processes. The cognitive processes in such part/whole structuring involve at least: (i) activating and combining parts in idea-generation activities that relate to the problem context; (ii) selecting and evaluating promising parts that are retained for further exploration and structuring; (iii) dynamically interlinking parts in conceptual design through sorting into categories; (iv) re-interpreting parts and wholes; and (v) establishing, exploring and re-configuring structural relations as wholes. Below we cover each of these cognitive processes in more detail.

3.1 Activating and combining parts in idea generation

In terms of idea-generation activities in design, we view many of the affordances of sticky notes as benefitting rich, creative ideation of parts that can be combined into wholes. Finke et al. (1992) propose that there are several, representative types of idea-generation processes in creative contexts, with such ideation most commonly involving the retrieval of existing ideas from memory (e.g., words, phrases, concepts, objects) and the formation of associations to these ideas (perhaps resulting in novel idea combinations). Indeed, many theories of creativity emphasize the importance of *conceptual combination* for creative discovery (e.g., Finke et al., 1992; Hutchins, 2005; Mednick, 1962). Retrieval and association typically happen quickly and automatically via implicit cognitive processing, which can also support rapid and intuitive idea synthesis and idea transformation (Ball & Christensen, 2020).

Idea-generation activities in design, such as retrieval, association, analogical reminding, synthesis and transformation, are activities that can readily be supported by the affordances of sticky notes. For example, the sheer ease of jotting down thoughts on sticky notes means that they form an excellent material to enable designers rapidly, easily and flexibly to externalize fleeting "ideational snippets" as key words, phrases and depictions (Ball & Christensen, 2020). This in turn means that it is straightforward for designers to populate a conceptual solution space with unstructured and unconstrained ideas or aspects of ideas (one per sticky note) for later creative exploration through the subsequent re-arrangement and re-structuring of sticky notes. It would seem that the key affordances of sticky notes that are of greatest value for idea-generation derive from their small size, which invites the informal entry of a single idea per note, their capacity to support speedy note-making and the way in which they provide a highly flexible and intuitive interface for rapid textual or visual expression. Additionally, combinations between notes are supported by their movability and tangibility. These two properties provide affordances that enable depicted ideas to be moved, shuffled and placed into association with other ideas, allowing for a progression from parts to wholes.

In combining ideas, sticky notes are geared toward the dynamic exploration of inter-note associations through their physical movement (also involving gesturing, gaze and verbalization in a team context) and through the eventual re-positioning of the notes (Christensen & Abildgaard, this issue). Such associative explorations often enable progress to be made when a multitude of seemingly disconnected notes have been generated, bringing some sense of relational order or integrated wholeness to what initially appear to be separate ideas or aspects of ideas. Such associative explorations typically also make use of the physical distance between notes to demarcate the associative strength between parts, ideas or concepts.

3.2 Selecting and evaluating parts for exploration and structuring

In terms of creative idea exploration in design, an important role is played by "idea selection", whereby good ideas get retained for further development and poor ideas get screened out. Idea generation in design is wasteful and most ideas that are produced are unlikely to be used in the final design concept. With respect to the affordances of sticky notes, their *ephemerality* is key in that an idea or aspect of an idea can at any one point be removed from the workspace and abandoned altogether. Indeed, after an initial phase of creative idea generation in design, a whiteboard will be populated with too many ideas to allow for all of these to be developed into a workable concept such that many need to be discarded, with a promising subset being maintained.

3.3 Interlinking parts and sorting parts into categories

Categorization involves analysis to derive more abstract meanings such as the grouping of parts under common headings. As argued by Dove et al. (2018), sticky notes can enable "category formation" and "category development" by supporting the inherent qualities of semantic memory, which can be conceptualized as a network of interconnected concepts (Anderson, 1995; Collins & Loftus, 1975). As such, sticky notes can be viewed as representing individual "nodes" in an emerging semantic network, with the relative physical distance between sticky notes mirroring the associative strength between the individual ideas represented (see also Christensen & Abildgaard, this issue). The re-fixability of sticky notes means that they can easily be moved and relocated in ways that indicate either category membership or category dissociation (including opposition, contrast and incongruity), whereby physical distance can reflect both within-category and between-category associative strength.

Dove et al.'s (2018) study of naturalistic sticky-note usage in expert design found that sticky notes can facilitate the process of moving from uncertain category membership towards clearer classifications, which can aid the ongoing creative process. However, Dove et al. also observed that designers had difficulties in visualizing *hierarchical* relationships within categories using sticky notes such that explicit gesturing and dialogue remained critical for supporting this process.

3.4 Re-interpreting parts and wholes

In their discussion of exploratory processes in creative ideation, Finke et al. (1992) suggest several processes as being important, one of which is "attribute finding". This involves searching for emergent features in preinventive structures, such as analysing a written word or phrase to find more nuanced interpretations. A related exploratory process noted by Finke et al. is "conceptual interpretation", which refers to the process of taking a preinventive structure and analysing it to derive an abstract, metaphorical or theoretical interpretation. In both cases the exploration process is concerned with the "interpretation" of already-generated ideas.

In design situations where ideas have been captured on individual sticky notes, interpretive processes will often involve designers visually scanning and re-attending to the ideational content of these sticky notes with the goal of identifying emergent meanings that go beyond the inherent ambiguity of jotted-down words, phrases or sketches. In this way, the information content on sticky notes can energize highly creative and divergent interpretations and re-interpretations of externalized

ideas. Indeed, in the design literature there is much established theorizing that speaks to the importance of ambiguity and uncertainty in externalized representations as a key driver for idea exploration (e.g., Ball et al., 2010; Ball & Christensen, 2009, 2019; Christensen & Ball, 2018; Fish & Scrivener, 1990; Goel, 1995; Purcell & Gero, 1998).

3.5 Establishing, exploring and re-configuring structural relations as wholes

The *relatability* of individual ideas and the *buildability* of parts into larger concepts, networks, and models, are key characteristic of exploratory cognitive processes in design (Ball & Christensen, 2020). The movement of sticky notes to establish new structural relations enables the designer to work towards more complex concept "build-up", including the specification of cause and effect relations between notes as well as the identification of temporal or functional contingencies and hierarchical embeddedness (e.g., to represent components and sub-components). Such movement towards creating new structural aspects of the conceptual whole typically takes the form of inter-note markings such as arrows, lines or brackets that are depicted on interconnecting sticky notes or directly on the board onto which sticky notes have been placed.

As for association, the key properties of sticky notes for supporting the generation of new structural relations pertain to note movability, combined with the visual support for judging and interpreting emergent features as a consequence of adding, changing or removing structural sub-components to the overall concept. Furthermore, the uniform size, shape and color of sticky notes combined with their ephemerality invites designers to view notes as "variables" that are exchangeable in terms of their positions within a relational structure. By exchanging one sticky note for another that is thence discarded, but simultaneously maintaining the overall structure amongst the notes, it is possible for designers to explore new emergent qualities.

Sticky-note use thus provides a window into the generation of new structural relations in conceptual design. Whereas previous cognitive theorizing has focused mainly on the processes that relate to recognizing and retrieving structures from past exemplars (e.g., structural retrieval and mapping; Christensen & Friis-Olivarius, 2020; Gentner & Markman, 1997), sticky notes may help us understand how design structures are *generated* in the first place.

4 The capacity for sticky notes to support design collaboration

In the previous section we have explained how sticky notes support design cognition through their capacity to facilitate a variety of cognitive processes that appear to be centrally concerned with understanding and reasoning about part/whole relationships in concept development. But what about the capacity for sticky notes to support design collaboration? Research efforts to uncover how socially-oriented creative interactions are sequentially co-constructed through the use of sticky notes have typically made use of methods such as ethnomethodology (Garfinkel, 1967) and conversation analysis (Sacks, 1992) with a multimodal focus (Hindmarsh et al., 2010). Micro-studies that draw upon such approaches are well-attuned to exploring the affordances associated with people's ongoing social interplay with sticky notes and other design materials, which are viewed as semiotic resources that help to enable social interaction.

In one such study, Nielsen (2012) examined "facilitated brainstorming" from a multimodal perspective and showed how multimodal orientation toward a range of semiotic resources, including sticky notes, is used to manage topical talk, elicit talk from a particular person, manage speaker transitions, secure progression and shifts, perform shifts in participant identity and elicit talk that performs particular social actions, explanations and accounts. More specifically, Nielsen demonstrated how the use of material objects during institutional interaction affords cognitive actions and makes it possible to externalize internal and individual processes to enable communication (cf. Streeck, 1996, 2009). Through her studies of authentic multimodal meetings, Nielsen (2012) showed how facilitators use sticky notes or colored cards to help participants turn ideas and individual cognitive processes into "talkables", which were then available for the group to address. Materialization of ideas onto sticky notes thereby allowed for visual support of social exchanges to enable further exploration, interpretation, development and critique of each of these ideas (Due, 2014), and their interconnections (Christensen & Abildgaard, this issue).

In the context of group brainstorming, Abildgaard (2020) proposed that sticky notes function as a "baton" for sharing individual ideas within the group, whilst also enabling collaborative idea construction and idea continuation. She further observed that sticky notes provide inspiration and visual cues for the generation of new ideas, with specific brainstorming instructions also serving to modulate social interaction and verbalization (cf. Matthews, 2009). Material structures such as sticky notes can therefore offer a comprehensive scaffold in situations such as creative design, enabling

participants to engage in the same imagination space through visible, accountable social actions (Due, 2018), helping to co-construct a shared social understanding (Casakin et al., 2015).

Christensen and Abildgaard (this issue) conducted a visuospatial analysis of the temporal dynamics of sticky-note usage in socio-material interaction. They zoomed in on micro-episodic sticky-note "moves" in a group context to investigate why and how designers move sticky notes around on boards. They found that the structure of individual sticky-note moves is characterized by stable, sequential steps containing multi-modal strategies for directing and maintaining "shared attention". Similarly, Ball and Christensen (2020) note that within group brainstorming settings, providing each group member with a set of sticky notes to write on minimizes the cost of members having repeatedly to shift their attention to listen to other people's ideas and also reduces communication bottlenecks that arise when group members have to wait their turn to have their idea heard. In this way, sticky notes may help to counteract group "productivity losses" in brainstorming (see Nijstad & Stroebe, 2006).

Speaking to the ability of sticky notes to engage a wide range of users in participatory design, Rakova and Fedorenko (this issue) examined how collaborative ideation with sticky notes emerged as a technique to challenge office hierarchies and bridge power differentials within Korean corporate culture. They concluded that sticky notes coordinated participants' actions, and effectively silenced domineering senior participants, thereby amplifying the opinions from junior and mid-career participants.

Beyond the aforementioned affordances that sticky notes can provide for shared attention during ongoing design work, it is also interesting to reflect on how material objects have been shown to retain "memories" of local interaction and meaning construction (Engeström, 2008; see also Matthews et al, this issue). Such mnemonic cues can benefit future social encounters, thereby enabling interacting participants in material surroundings to connect with previous uses of the artefacts (Streeck, 1996, 2009). Whilst sticky notes are often used to support group processes during a single design session and are subsequently discarded, they may also serve to hold memories of group processes and team decisions across time (Christensen et al., 2020b; Fischel & Halskov, 2020). Indeed, Dove et al. (2018) found that the sticky notes that were generated by a design team in conjunction with lead users and stakeholders during a 4-month long design process served to retain and structure group processes across sessions and allowed for the "share-back" of information from

in-field encounters and user sessions (cf. Shroyer et al., 2018). In some cases, previously filled-in sticky notes were even brought along on travels across borders to support further team processes.

5 Digital sticky notes

The popularity of the sticky note as a design material has led to many attempts at transferring sticky-note qualities into a digital context, fueled in part by the increasing amount of online collaboration arising during the COVID-19 pandemic. Popular, online, sticky-note collaborative systems (e.g., Miro; Mural) and experimental research platforms such as Cards and Boards (Dalsgaard et al. 2020), aim to capitalize on many of the affordances found in physical sticky notes, often preserving elements such as their colors and sizes, but changing other aspects in order to infuse new digital possibilities. We cover here some of the ways in which digital "sticky-notes-on-boards" afford design cognition and collaboration in different ways from their physical counterparts.

Digital sticky notes are commonly placed on canvases that correspond to the flip charts or whiteboards that pervade the physical world. The notes can be moved smoothly across these canvases, evading issues with the finite number of times a physical sticky note can be moved before it tends to fall off a surface. Indeed, digital instantiations of sticky notes often afford even more flexible movement and re-movement of notes compared to physical versions (Jensen et al., 2018). Digital canvases can be simultaneously displayed on multiple screens, including large-sized, multi-touch screens and personal devices like tablets, thereby supporting not only co-located activity but also distributed collaboration, both synchronous and asynchronous. An additional quality of sticky notes on digital canvases is that they can easily be archived for later use and they can also readily be shared in later sessions, unlike the cumbersome storage of physical notes on flipcharts. Digital instantiations often enable the manipulation of both the size of the board, as well as the size of individual sticky notes, allowing for the entry of more information, as well as additional types of content (including hyperlinks, images and videos; e.g., see Dalsgaard et al., 2020). In a digital context, notes can be copied, re-colored and edited without the ability to identify through handwriting who did the editing (Fischel & Halskov, 2020).

Such design choices may impact on the social interaction that takes place with digital sticky notes, and the collaborative experience of using digital sticky notes is often markedly different from the experience that arises when activities are carried out with their paper-based counterparts. For example, by allowing for the manipulation of notes and adjustments to the board size, the entry of layered note content is rendered possible that is not readily visible to all (e.g., via hyperlinks). In

addition, the availability of individual zooming and viewing options in relation to very large boards, together with limited opportunities to identify collaborators' gestures and gaze directions, means that digital instantiations of sticky notes are often less effective at supporting the establishment of shared material anchors, unambiguous reference points, joint attention and turn-taking (see Matthews et al., this issue). The operation of "shaking" a digital sticky note seems analogous to the gestural activity of holding or pointing to physical sticky notes and is carried out extensively in digital contexts (Jensen et al., 2018).

The previous discussion of digital sticky notes points toward some inherent ironies of digitization. For example, with the capacity to include links, video and other layered information in digital sticky notes, it may become more difficult to retain sticky-notes-on-boards as a shared visual reference point in support of collaboration. In addition, the level of technical skill required to engage in online sticky-note creation may likewise increase, potentially making participation more difficult for some users, and decreasing the speed and intuitive application of sticky notes in ideation. With these ironies in mind, it is interesting to note that a comparative study of physical versus digital sticky notes conducted by Bødker et al. (2020) identified two main differences in terms of user preferences. First, physical sticky notes are preferred by designers when initially generating note content. Second, digital sticky notes are felt by designers to be easier to move around on boards once they have been generated. Similarly, Dalsgaard et al. (2020) report that their studies show that digitization makes the process of sorting, re-arranging and editing sticky notes much easier than is the case with their physical counterparts. In a recent comparative study of physical and digital sticky notes, Frich et al. (2021) established that the digital tool, in comparison to use of physical sticky notes, potentially leads to an increase in convergent thinking in the design ideation process.

These aforementioned observations point to the value of *supplementing* physical whiteboards rather than replacing them altogether. This is an endeavor that has been pursued by Geyer et al. (2020), who explored how to augment physical sticky notes in a digital environment. The resulting *hybrid* setting thereby aims to combine the best of both worlds in terms of "The high utility and usability of paper sticky notes together with 'magical features' of digital technologies" (Geyer et al. 2020, p. 126).

6 Conclusions and future directions

In this conceptual position paper, we have addressed the research question of *how* sticky notes support design cognition and design collaboration when compared to other kinds of design materials.

In tackling this question, we first considered the importance of "design materials" in design activity, exploring the critical roles played by sketches, prototypes and card-based resources, before then engaging in a comparative examination of the role of sticky notes in design. We proposed that all four design materials have various characteristics in common, including their critical capacity to function as preinventive structures (Finke et al., 1992), representing fragmentary solution ideas that can facilitate creative discovery through novelty, ambiguity, implicit meaningfulness, emergence, incongruity and divergence. Beyond such common features, however, we also demonstrated that sticky notes have inherent properties (i.e., paper, size, shape, color and stickiness) that jointly afford a set of unique and distinct activities relative to other design materials. Such affordances include the fact that sticky notes are relational, re-configurable, decomposable and categorizable. These affordances make sticky notes highly suited to many diverse aspects of design cognition that are associated with idea generation and conceptual design, including cognitive processes that are centrally concerned with the dynamic generation and exploration of "part/whole" relationship in concept development (e.g., conceptual combination, categorization, re-interpretation and structure generation).

Sticky notes have long been praised for the visual support that they provide to design processes. However, we have attempted here to go beyond such basic, high-level descriptions in order to show more precisely how the visual, diagrammatic representations of part/whole relations facilitate well-known creative cognitive processes such as categorization, association and the development of structural relations through perceptual and motor acts related to proximity and physical object movement. Furthermore, we have attempted to explicate why "tangibility" assists in supporting shared attention and collaborative design dialogue through the provision of material anchors, and the enablement of physically referencing objects through gesture and gaze. In addition, sticky notes support joint attention by turning individual cognitive processes into "talkables" and through the management of turn-taking that helps direct team-based design progress.

The sheer variety of ways in which sticky notes facilitate the processes of collaborative idea generation and conceptual design, which covers much of the basis of core design work, provides a ready explanation for their ongoing popularity in real-world design practice. We have argued that to disregard the humble sticky note as a key support material in creative design is to ignore a whole sphere of cognition that underpins effective real-world design practice that is central to contemporary design. We have additionally alluded to the fact that there is no *single* property of sticky notes that helps to support all aspects of design cognition and design collaboration. Rather, sticky notes have a

range of properties that each serve either individually or in combination to support idea generation and conceptual design activities. Furthermore, it is not the case that sticky notes will always support all aspects of design perfectly, as some of their properties also bring limitations, such as the fact that their stickiness (and therefore their capacity to be moved about and re-fixed) is finite. Exploring such limitations of physical sticky notes and the potentially superior affordances (as well as unique limitations) of *digitally infused* sticky notes represents an important direction for future design research. More generally, there is a need for design research to trace sticky-note usage across physical, social, cultural and temporal contexts to explore fully the "social life of sticky notes".

There are numerous other lines of useful research to explore relating to the use of sticky notes in design, including the need to develop a deeper understanding of: (i) the cognitive strategies deployed in the generation of new conceptual structures through the gradual building-up of parts, (ii) the nature of expert versus novice differences in sticky note usage, and (iii) the ways in which sticky notes can be digitally infused with capabilities for further supporting part/whole relationships without losing the beneficial affordances of the paper-based version. To date we have clearly only been scratching the surface of sticky-note usage in design, which – to reiterate – is highly paradoxical given their ubiquity that derives from the sheer versatility of sticky notes as a design material. We look forward to future empirical research and theorizing that will continue to advance our understanding of the power of the humble sticky note in design practice.

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