Grouping notes through nodes: The functions of Post-It notes in design team cognition

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We investigate the way Post-It notes support creative design team practice, focusing on how they function as cognitive externalisations that, through grouping activities, support categorisation qualities associated with semantic long-term memory. We use a multimodal approach, drawing on ethnomethodology and conversation analysis, which places gestures and interactions with Post-It notes on a similar footing to speech and text. This highlights the role of these interactions in the situational context, as the design team shape and are shaped by them. Following Dix and Gongora (2011), we identify four overlapping functions: informational, formational, transformational *and* transcendental. *We then examine the emergence of concepts and themes through grouping individual Post-It notes, showing how they might be considered nodes in an emerging semantic network.*

Keywords: Post-it notes, design cognition, design tools, collaborative design

The humble *Post-It note* is one of the most frequently used materials in creative practice. For instance, they play an important role in affinity diagramming as part of contextual design (Beyer & Holtzblatt, 1997, pp. 154–163), and in the brainstorming activity in Future Workshops (Kensing & Madsen, 1991). In this paper, we investigate the functions these small sticky notes play in design cognition. In particular, we consider their use in terms of the *cognitive support* they provide for the design team's creative practice in the sessions recorded for the DTRS11 dataset (Christensen & Abildgaard, 2017, pp. 19–37) from the Design Thinking Research Symposium in 2017 (Christensen, Ball & Halskov, 2017).

To frame our understanding of cognitive activities, we draw on the theory of distributed cognition (Hollan, Hutchins, & Kirsh, 2000; Hutchins, 2006), which shows us how cognitive processes may be distributed across the

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members of a social group, through periods of time, and may involve coordination between internal (i.e. mental) and external (i.e. material and environmental) structures. To investigate the way Post-It notes are used during the design activities recorded for DTRS11, we draw upon literature discussing the functions design materials and artefacts serve as *externalisations* (Dix & Gongora, 2011) that aid reflective design practice (Schön, 1992). We also investigate the way in which collections of Post-It notes are clustered and grouped, as this phenomenon is such an important aspect of their use in creative practice. To support this additional level of analysis, we make reference to theories of *categorisation* in *semantic long-term memory* (Collins & Loftus, 1975).

1 Post-It note use in design practice

Despite being commonplace, the practices surrounding designers' use of Post-It notes have not, to our knowledge, previously been the subject of close analysis and theorising. Where they have been discussed, it has typically been to compare the use of digital implementations with paper Post-It notes during common ideation activities (e.g. Harboe & Huang, 2015; Hilliges et al., 2007). This is in contrast to comparable design activities, such as sketching (Buxton, 2010; Purcell & Gero, 1998; Stolterman, 1999) or prototyping (Lim, Stolterman, & Tenenberg, 2008), which have been studied closely in their own right. However, the value of informal paper-based design tools is commonly acknowledged (Cook & Bailey, 2005). For instance, Post-It notes are commonly used to capture individual ideas and form categories when brainstorming, support design thinking and design outcomes (Christensen & Ball, 2017, pp. 249–269), and can be used in synthetic or compositional activities (Stolterman, McAtee, Royer, & Thandapani, 2009). An example of this is *affinity diagramming*, a technique that uses Post-It notes to derive meaning out of data drawn from user studies (Beyer & Holtzblatt, 1997, pp. 154–163).

1.1 Properties of Post-It notes

Post-It notes are characterised in part by their regular shape and small size. This makes them ideal for carrying small, self-contained pieces of information, and results in them typically being used to represent a single idea. They have a strip of semi-permanent, reusable adhesive along their top edge, which allows them to be positioned (and later re-positioned) relative to other Post-It notes; e.g. on larger sheets of card or a whiteboard. This facility to intentionally position and re-position Post-It notes relative to each other also makes it possible for the connections between different Post-It notes to become meaningful. Post-It notes are also available in a number of different colours, which allows intentional selection of colour to carry semantic value. Finally, individual Post-It notes are of little value in themselves and, can therefore be easily discarded if the idea they contain is no longer considered important. In summary, Post-It notes can be considered capable of flexibly carrying symbolic

representations of individual ideas; and also of representing larger, emergent concepts through grouping and associations of position and colour.

2 Externalisations in design activities

Externalisations are ubiquitous in design work, providing intellectual resources that help make the tacit explicit, facilitate reflection on embodied action and enable designers to shape the world as a resource to support design activities (Dix & Gongora, 2011). As such, externalisations must evolve as complex problems develop and situations are transformed, and therefore be both expressive (mutable) and associative (combinable) (Fischer, Nakakoji, & Ostwald, 1995). In doing so, they serve an important role in contextualising information and creating objects to think with (Arias, Eden, Fischer, Gorman, & Scharff, 2000), and also in facilitating a shared understanding of the design work at hand (Warr & O'Neill, 2007).

Dix and Gongora (2011) describe externalisation as a process of embodying, representing and exploring thoughts and feelings; and of having the overlapping purposes of generating, elaborating and communicating ideas. This is the core theoretical lens we use to analyse how the design team work with Post-It notes in the DTRS11 dataset (Christensen & Abildgaard, 2017, pp. 19–37), and it provides us with four functions that can be ascribed to design externalisations.

2.1 Informational

When serving an *informational* function, an externalisation is communicative, and explicitly expresses one person's idea so that someone else can share a similar understanding. This is one of the most familiar uses we might think of for Post-It notes in collaborative design activities; for example, when one individual writes an idea on a note and shares it with other design team members.

2.2 Formational

An externalisation serves a *formational* function through helping to bring an idea into being; that is, the idea is itself being formed during the externalisation process. For example, we might imagine a designer who starts to write one Post-It note, and for whom the act of writing triggers further ideas, which in turn are written down.

2.3 Transformational

The *transformational* function of externalisations is to support continuing cognitive activity; that is, the "backtalk" in Schön's (1992) description of design as a conversation with the materials of a situation. An example of this during collaborative design activity would be the way in which an idea donated on a Post-It note by one team member might be modified by a

Post-It note that is subsequently added, either by that design team member or by another.

2.4 Transcendental

The *transcendental* function of externalisations supports designers' structuring and manipulation of ideas, prompting new concepts and insights to emerge. Dix and Gongora (2011) describe this as meta-cognitive. The act of expressing ideas externally, for example through symbolic representations such as Post-It notes containing words or sketches, facilitates designers' thinking about concepts, arguments, criteria and the like as if they were any other kind of 'thing.' In this way, the designer can work with the material of ideas much as one might arrange images for collage, or build with LEGO. A common example of this during design activities would be the way in which collections of Post-It notes are revisited and reorganised in order to re-conceptualise the ideas contained on individual notes or captured within clusters. Such knowledge and control of cognitive processes has been shown to be important to creativity (Armbruster, 1989).

In our analysis, we highlight examples of each of these different functions served by the Post-It notes used by the design team. However, these four functions should not be considered discrete labels that can be applied atomically to particular use cases; rather they should be considered different aspects of complex overlapping patterns. Through this we show how Post-It note use supports the design team's creative practice, and connect our understanding of the different functions Post-It notes serve to previous research.

3 Categorisation in semantic long-term memory

The use of Post-It notes during design activities may be similar to sketching in the way it supports a range of cognitive processes. This can include idea access and individual re-interpretation (Van der Lugt, 2005), chunking (Suwa & Tversky, 1997), and analogical reasoning (Christensen & Schunn, 2007). In the present paper, we illustrate how the use of Post-It notes during clustering and organising exercises may facilitate category formation through its support for the qualities of semantic long-term memory.

Classically, semantic long-term memory is conceptualised as being constituted through associations of nodes in a network (Collins & Loftus, 1975). A key feature of this model is that semantic recognition follows patterns of activation that spread amongst different nodes (concepts) via pathways stored between those nodes that have become associated. No single feature is necessary for judgments of category membership, as concepts have a graded structure, and such judgments are considered contingent on the typicality of the potential member. The semantic relationship between different concepts can be characterised by their conceptual overlap, and the strength and length of associated

pathways between their nodes. This is evidenced by the relationship between the time taken to judge category membership and the centrality of the potential member within that category. It has also been shown that the pathway distance between any two concepts may be estimated dependent on their conceptual overlap. In addition to associative strength within and between nodes, concepts also have hierarchical relations to both superordinate and subordinate level concepts (Rosch, 1978). As a result of these various cognitive qualities related to semantic long-term memory, fuzzy boundaries often exist between categories, and membership may be uncertain. These qualities exist in natural language categories, as well as in *ad-hoc* categories constructed for situational purposes (Barsalou, 1983).

4 Method

To explore the functions Post-It notes serve in design team practice, we analysed video data drawn from the DTRS11 database (Christensen & Abildgaard, 2017, pp. 19–37). The database consists of *in-situ* video recordings of a professional design team as they work through a specific design task for a worldwide manufacturer within the automotive industry. The data include collaborative design activities at various stages of the design process, and co-creation sessions with lead users, in both a Scandinavian and a Chinese context. The design team recorded during the activities that make up the DTRS11 dataset includes the following members featured in the videos we have analysed: Ewan: Lead Designer; Abby: Designer; Kenny: Designer; Rose: Chinese Consultant; Nina: Design Intern; Tiffany: Stakeholder from the parent company.

Our analytical approach is multimodal, drawing on ethnomethodology (EM) and conversational analysis (CA) (Streeck, Goodwin, & LeBaron, 2011). Interaction is considered to be more than just speech and text (Kress, 2009), and we aim to award Post-It notes a status that renders them analysable without diminishing the significance of human interaction. In this way, we explore how the design team's use of Post-It notes is an integral part of their interaction and communication. Following EM, we highlight the role Post-It notes play in the situational context as they are actively used by the design team, who shape them, are shaped by them, navigate by them and make sense in relation to them (Goodwin, 1994). Having first watched the entire collection of videos in the DTRS11 database to gain an impression of the overall activity, we selected three videos to investigate closely: V3, V15 and V18. These videos were selected, because they illustrate diverse aspects of the design team's Post-It note use. In V3, we observe the design team forming categories by clustering and grouping Post-It notes containing ideas generated individually in a brainstorm session. In V15, we observe the design team generating and sharing insights based on the outputs from the co-creation sessions held with Chinese lead-users. In video V18, two members of the design team revisit these ideas

in preparation for a share-back session with the wider project team. These three sessions enable us to analyse the design team's use of Post-It notes in different activities, and to track their use of Post-It notes across different phases of their design process.

To begin with, each Post-It note appearing in a videoed session was given a reference number based on the order in which they were added to the wall or the whiteboard. This resulted in Post-It note 'maps' showing the final position of the Post-It notes in each session, and containing temporal information about their use during that session; e.g. how they were placed and/or moved as part of the design activities. As part of this map-making process, the content of all the Post-It notes was transcribed, and listed along with a reference number. Selected maps are included as illustration in this paper. This approach is similar to the one Shroyer, Turns, Lovins, Cardella, and Atman (2017, pp. 521–540) use in their "Level 3" analysis of an ideation session from the same DTRS11 dataset, which includes analysis of Post-It note generation and placement, and is also included in this special issue. In V15, the insight sharing session, a number of Post-It notes that were written in Chinese but partially translated into English by the Chinese consultants had been brought in from previous co-creation sessions. In these cases, only the English text was transcribed.

Alongside our study of the videos and Post-It note maps, we also investigated transcripts of each session, augmenting these with details of overlapping speech, gesture and gaze. Gesture and gaze direction are important features to note, because they help establish when a particular space becomes a shared focus for cognition and action (Streeck et al., 2011). In particular, selected extracts from the transcripts were expanded to include detailed notations of Post-It note use; e.g. who wrote the note, when it was written, when it was placed on the wall or whiteboard, where it was placed, and when it was referred to (verbally or non-verbally). This enabled us to focus strongly on the role the Post-It notes played in design conversations. This CA-inspired transcription allowed the creation of highly accurate and reliable transcripts as a foundation for our subsequent analysis. Adding graphics and gestural observations to these transcripts helped reveal the relationships between the conversation and the recorded interaction (Heath, Hindmarsh, & Luff, 2010, pp. 73–82). This multimodal analytical approach, in which different kinds of qualitative data are considered, results in a nuanced picture of what is happening during design activities, and helps us triangulate particular findings.

Finally, independent groups of researchers in Copenhagen and Aarhus, Denmark, categorised selected examples of Post-It note use, according to our chosen theoretical frameworks. Agreement was then sought between each group of researchers with regard to the roles and functions served by Post-It notes in each of these examples.

5 Findings

In this section, we present examples of Post-It note use for each of four functions that externalisations serve in design practice: *informational*, *formational*, *transformational*, and *transcendental* (Dix & Gongora, 2011). As we show, these are not discreet functions assigned to particular Post-It notes on a one-to-one basis; rather, they are typically present in combination. We also show how Post-It notes can support the cognitive processes associated with category formation and semantic long-term memory. Here, we pay particular attention to the temporal development of Post-It note placement during design ideation.

5.1 Summary of findings

We find clear evidence of Post-It notes serving each of four functions ascribed to design externalisations by Dix and Gongora (2011), but it is rare that these functions are seen in isolation. Rather, the way design activities unfurl temporally seems to require a more complex pattern in which Post-It notes serve multiple functions. This is supported by the physical properties of Post-It notes (e.g. colour, size and the strip of glue that enables them to be temporarily fixed or easily repositioned), which allow the Post-It notes to 'evolve' into more complex forms and groupings, act as objects to think with, and provide grounds for a common understanding of the work at hand. We see least evidence of Post-It notes serving a *formational* function. However, further study is needed before we can say if this is a result of the physical properties of Post-It notes or a reflection of this particular design team's practice.

We also find evidence to back up the hypothesis that Post-It note use supports qualities associated with semantic long-term memory, particularly during clustering activities. Here, we see evidence that positioning and moving can indicate membership or dissociation, and that distance can indicate both within and between category associative strength. However, there are also clear limitations in the way that clustering Post-It notes on a whiteboard results in a two-dimensional layout, as this makes visualising hierarchical relations within categories difficult. To achieve and maintain these hierarchical distinctions, we see repeated gesturing and dialogue to augment the clustering activity.

5.2 The functions Post-It notes serve as externalisations of design cognition

We use examples from two design activities to illustrate our findings regarding the externalisation functions that Post-It notes serve in design cognition. First, we look at V18, in which Abby and Kenny reflect on the Post-It note collections they have labelled 'Product', 'Sales' and 'Story'. They do this in order to distil the insights contained in preparation for a share-back session with the entire project team. Following this, we look at V15 in which Rose, Kenny, Abby, Nina, and Tiffany are sharing insights from a co-creation session held

with Chinese lead-users over the previous two days. In this session, Rose is translating Chinese language Post-It notes into English.

In the session recorded for V18, we first see Abby and Kenny spend almost six minutes, silently considering three groups of yellow and green Post-It notes labelled 'Product', 'Sales' and 'Story' (Figure 1). These were generated when insights from earlier co-creation sessions were shared, and here they provide inspiration for a new round of individual ideation, which is recorded using orange Post-It notes. This activity follows a repeated pattern in which the two designers look carefully at the existing groups of yellow and green Post-It notes, and then look down to write ideas on new orange Post-It notes. During this time, their gaze and focus change, as they reflect on different areas of the boards containing the three Post-It note clusters. Here, we see Abby and Kenny creating links between the existing Post-It notes and the new notes they each silently produce. This process of identifying similarities and linking ideas is later verbalised when Abby and Kenny discuss and share their new orange Post-It notes. During this activity, Post-It notes are objects for reflection-in-action (Schön, 1992), making it possible for Kenny and Abby to identify new connections, and to think and talk about their previous thoughts at a conceptual, meta-cognitive or *transcendental* level.

As the activity unfolds, we see Abby and Kenny interact with the yellow and green Post-It notes in the 'Product', 'Sales' and 'Story' groupings simultaneously with the orange Post-It notes they have just been writing (Figure 2). Here, each of the Post-It notes referred to serves the *informational* function of communicating an idea expressed by a design team member; e.g. yellow Post-It note #63 with its circular 'Production -> sales -> consumer -> trash -> recycle ->', and orange Post-It note #4 'Environment & recycling'. However, we also see these Post-It notes serve both *formational* and *transformational* functions, often concurrently. For example, as we see in the transcript extract

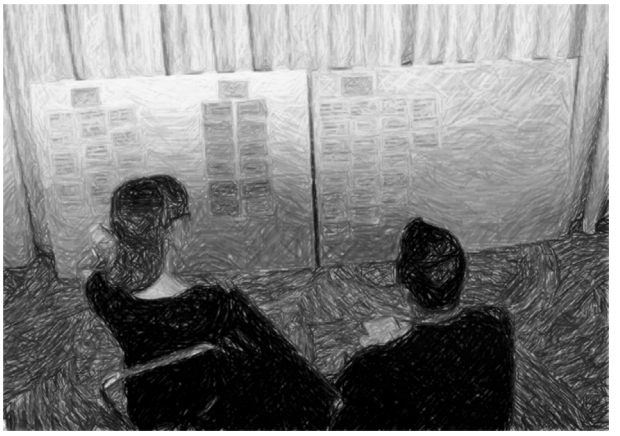

Figure 1 Post-It notes serve a transcendental function that supports Abby and Kenny's reflection during V18

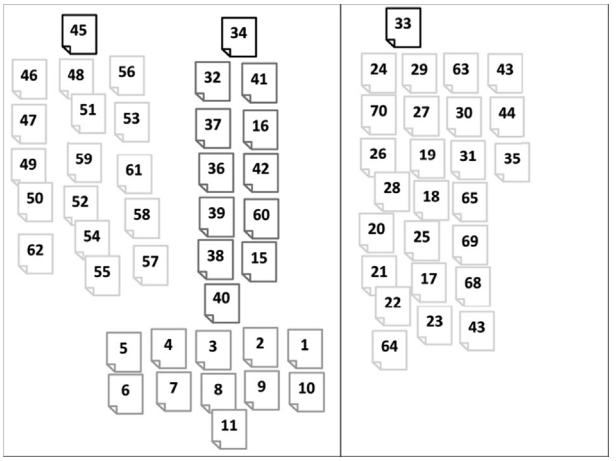

Figure 2 A Post-It note map from our analysis of V18, showing the three initial clusters plus the new ideas Kenny and Abby have added

in Figure 3, Kenny brings forward the idea of 'environment' in relation to 'product life cycle' at 30:53. This acts as a prompt for Abby who then relates this to their other ideas saying, "It definitely belongs underneath something." In this extract, the idea that eventually becomes orange Post-It note #4 'environment & recycling' is formed and expressed, and is then used to organise and transform their current thinking.

30:53	Kenny	Ehh and "recycling" (..) But like all of the cycle.	((Points and makes a circle at English Post-It note #63 'Production -> sales -> consumer -> trash -> recycle ->))
30:56	Abby	Yeah. That one-	((Points at the same Post-It note))
	Kenny	Yeah. That one. And maybe it should be called something with "environment"	((Looks up at Post-It section 'Story'))
31:06	Kenny	But what I MOSTLY saw in it was this thing with this "product life cycle". (..) (5.5 seconds pause)	((Points and makes a circle at English Post-It note #63 'Production -> sales -> consumer -> trash -> recycle ->))
31:13	Kenny	I don't know what we should call- if it deserves its own, but I-	
31:17	Kenny	But we don't really have anything with "environment".	((Points at the Orange Post-It notes #1, #2, #3 on wall))
	Abby	No. Maybe it's good to bring in.	
31:23	Kenny	Yeah	((Begins to write on Post-It note #4))
31:24	Abby	Definitely (.) I mean, yes, bring it in, but I think it definitely belongs underneath something, I mean it's the way- there just so many many annoying dust mice everywhere here!	
	Kenny	Yeah. Maybe we can just call it "environment or recycling"	((Writes on Post-It note #4))

Figure 3 Extract 1, illustrating the formational *and* transformational *functions Post-It notes serve through the production of Post-It note #4 'environment & recycling'*

Once this idea ('environment or recycling') is written down, Abby and Kenny continue to reflect on how it fits into the wider collection (see Figure 4), first with reference to orange Post-It note #2 'Life time companion – personalisation – 3 in 1', and following this with reference to orange Post-It note #3 'Smart living, tech as an improvement of life'. Here, their thinking moves beyond the individual idea and Post-It note and on to its role in their larger conceptual framework. This reflection continues for a period beyond that included in our transcript extract, and ends with Abby re-positioning orange Post-It note #4 once more. It is evident throughout the activity analysed here that both Kenny and Abby are taking a meta-cognitive *transcendental* stance toward not only the particular Post-It notes being discussed, written and moved, but to all the Post-It notes in front of them.

The examples from this video also show how grouping Post-it notes creates new externalisations that reflect the development of higher-level concepts and themes. As this happens, different qualities of particular Post-It notes, such as colour and position relative to other Post-It notes, become important aids to clarifying and representing these concepts as they are emerging. Other qualities, such as the size of the Post-It notes typically used and the adhesive strip that allows them to be temporarily fixed or easily repositioned, are also important enablers in this process. This is because they facilitate a flexible overlapping of different functions as the Post-It notes evolve into more complex forms and groupings that match and support ideation. Kenny and Abby use Post-It notes, both individually and in groups, as objects to think *with* and to ground their common understanding of the situation at hand. In doing so, the functions served by individual Post-It notes can change, and they may take on additional functions, as we have demonstrated with the example of orange Post-It note #4, see Figure 3.

In the session recorded in V15, the design team share insights from a two-day co-creation workshop held with Chinese participants. Here, they are working with Post-It notes generated during the co-creation sessions, which are typically written in Chinese (shown mapped in Figure 5), and also with Post-It notes containing English translations of the ideas recorded on the Chinese language Post-It notes (mapped in Figure 6). We use examples from this video to

31:39	Abby	Yeah. Also, I mean, with it - I think so too, something goes (.)	
	Abby	I mean it might go underneath that one for example, that's something with,	((Points at Post-It note #2 'Life time companion - personalisation - 3 in 1))
31:51	Abby	I mean, and that one it might also belong to.	((Points at Post-It note #3 'Smart living, tech as an improvement of life'))
	Kenny		((Places post-note #4 'Environment & recycling' onto the wall))

Figure 4 Extract 2, illustrating the transcendental *function Post-It notes serve with Post-It note #4*

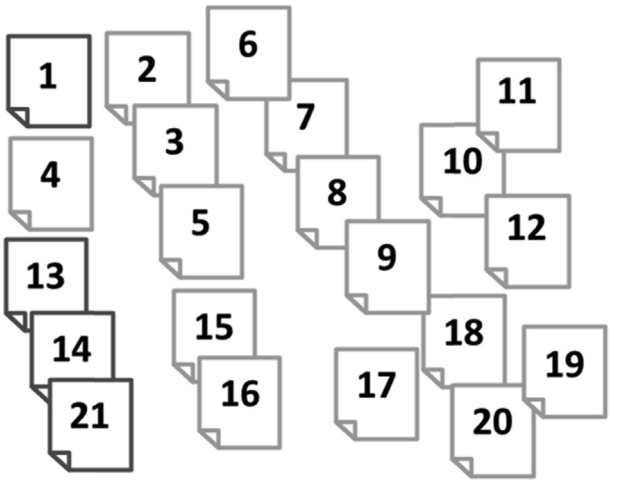

Figure 5 Map of Chinese language Post-It notes used in V15

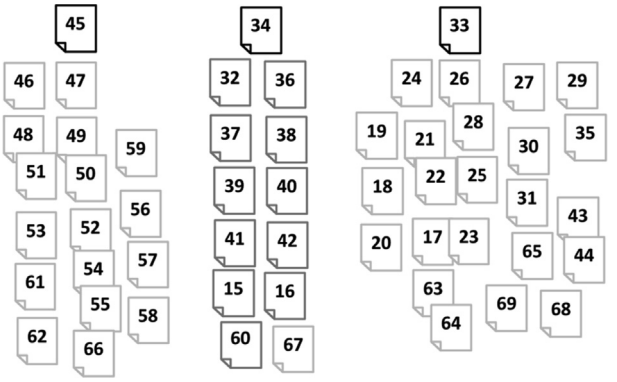

Figure 6 Map of English language Post-It notes used in V15

discuss in more detail the *informational*, *formational* and *transformational* functions Post-It notes serve during design activities. The transcript in Figure 7 shows Rose pointing to, looking at, and then making a circle gesture around the Chinese language Post-It #6 that says 'Online product/service'. It also shows Rose looking at Chinese language Post-It note #4 that says 'comprehensive/safety' at 31:20, which prompts her to remember that one participant suggested a service that is "comprehensive but also modular". In these examples Rose uses the Post-It notes as communicative resources to provide reference points and affirmations as she communicates the Chinese co-creation session participants' ideas to the design team. Here, the Post-It notes serve an *informational* function.

The transcript extract in Figure 8 shows the idea that is recorded on Post-It note #26 by Abby being formed and developed as she writes it. She starts by writing down 'Personal Aspect' at 38:36. These are words she has just

31:25	Rose	So this was what he was thinking of	((Circles at Post-It note #6 'Online product / service'))
	Tiffany	Yes, service is based on a product?	
31:29	Rose	Yeah, services based product	
31:31	Rose	Then the next was Ying. And then Ying was all about the service actually, he was thinking that it should be an online service that is comprehensive but also modular so that you can add the different types	((Looks up at Post-It note #4 'comprehensive/safety'))

Figure 7 Extract 3, illustrating the informational *function Post-It notes serve when Rose translates from Chinese into English*

previously said out loud. Then at 39:00, she adds an idea that has been voiced by Kenny, 'Different Kinds Of Interaction', before finalising her idea and finishing writing the Post-It note by adding 'Talk' at 39:36. 'Talk' is not a direct reference to something that is said out loud, but rather a modifying comment, which probably refers right back to the start of their current discussion when Rose was relating a story about a Chinese lead user who introduced the idea of talking with the car as if it were a boyfriend. This Post-It note, #26, is then added to the wall having served a *formational* function.

There were relatively few examples in which Post-It notes serve this *formational* function during the sessions recorded for the DTRS11 dataset, when compared to the other functions discussed here. This may be because the physical properties of Post-It notes, such as their typically small size, do not facilitate this function so effectively. It may also be a reflection of this particular design team's practice, as the video recordings show ideas almost always being developed through headline writing, and very few examples of other practices such as sketching. Further study is needed before we can say anything more authoritative about this.

The transcript in Figure 9 shows Kenny writing '2-Way Interaction' on Post-It note #28 at 40:08. He then carefully and deliberately attaches it to the bottom of Post-It note #26, which Abby had just previously placed on the wall (see Figures 10 and 11). Post-It note #28 has clearly been placed as a response to Post-It note #26, and from here on it modifies the future meaning of Post-It note #26 for the whole design team. The two Post-It notes (#26 and #28) become permanently linked to each other, and are treated as a single idea/note. In this example, Post-It note #28 is serving a *transformational* function in relation to Post-It note #26.

5.3 *Post-It note support for qualities of semantic long-term memory*

Attempting to form categories by grouping and clustering individual Post-It notes is a familiar design activity, and a typical part of brainstorming exercises,

38:36	Abby	Yeah (..) so it's (.) >I guess it's< more the personal level- personal- yeah- personal (.) aspect or::?	((Rose looks at the English Post-It notes #17-#24))
38:41	Kenny	Yeah because I- I think it's eh: it might	
38:41	Abby	Be different from person to person how they wanted to realize (.) so, it could be she wanted t- wanted to talk to you	((Writes 'Personal Aspect' on Post-It note #26)) ((Looks at English Post-It notes #17-#24))
38:52	Rose		((Places Post-It #25 on wall))
	Kenny	But other people would be maybe intimidated [by the car talking to you, so they would prefer different] kinds of interaction	
38:54	Abby	(.) Exactly	
	Rose	mhh yeah but [then there is k- >some kind of< interaction]I think that was what	
	Kenny	Like the person interaction that [makes you] feel like- that this has (.)a relation to me-	
39:00	Abby		((Writes 'Different kinds of interaction' on Post-It note #26))
	Nina	Yeah because that other guy said that he wants to be able to display it, and the other guy- even if you don't wanna display it, it sends you a report (..)	
39:12	Rose	Yeah (..) that was the: real time -whether you have regular or pushed notifications (.) or that you would look at at the same [time. So]	((Points and taps at Chinese Post-It note #43 'Alarm' with pen))
39:22	Rose	(.) I think (.) that because- that if they can provide you with push notifications like your REGULAR REPORTS (.) and then >at the same time< you would be looking at it ((touches her wrist)), but it would also: ehm: give me an alarm (.)[or like]you know if something needs to- it's, >I guess, I guess< it is the thing that now most (.) a-mobile product that,	((Points at Chinese Post-It note #43 'Alarm'))
39:36	Abby		((Writes 'talk' and places Post-It note #26 on wall))

Figure 8 Extract 4, illustrating the formational *function that Post-It notes serve through the production of Post-It note #26*

during which the Post-It notes may provide cognitive support for reflection and convergence. V3 records the design team brainstorming ideas for how they will conduct lead-user co-creation sessions in China. After silently producing individual ideas on separate Post-It notes, they then try to create categories of these ideas by clustering the Post-It notes. This clustering process takes place around a whiteboard (Figures 12 and 13), on which individual team members place their Post-It notes one-by-on whilst simultaneously discussing the placement of each Post-It note and possible category titles for emergent categories. Figures 14–17 illustrate the dynamics of Post-It note

40:08	Kenny		((Writes '2-way interaction' on Post-It note #28))
	Tiffany	Access to eh:: European [eh: (..)] specialists or whatever	((Rose looks at English Post-It notes))
40:14	Rose	[Yeah] I think this is good	((Looks at Chinese Post-It notes))
40:32	Kenny		((Sticks Post-It note #28 on the bottom Post-It #26))

Figure 9 Extract 5, illustrating the transformational function Post-It notes serve as Post-It note #28 is used to modify Post-It note #26

Figure 10 Kenny placing Post-It note #28 underneath Post-It note #26

Figure 11 Post-It notes #26 & #28 combined

placement during this clustering in four snapshots. In these snapshots, Post-It note numbers represent the order in which they are first placed on the board, and arrows indicate gesturing or verbal expressions of relationships between Post-It notes. By analysing the temporal development of the placement of Post-It notes in relation to the team dialogue and gestures, it is possible to

Figure 12 The design team brainstorming ideas during V3

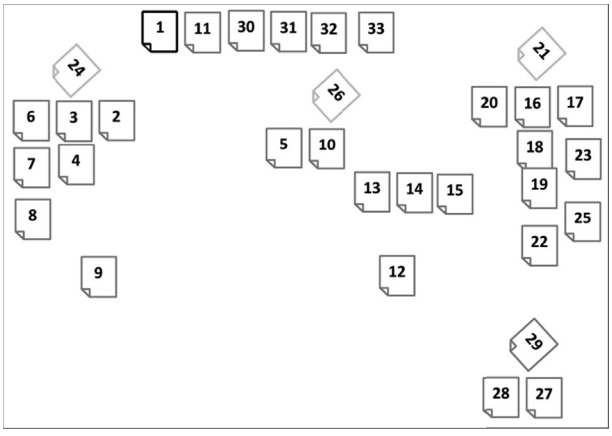

Figure 13 Map of the final positions of Post-It notes after the brainstorm in V3

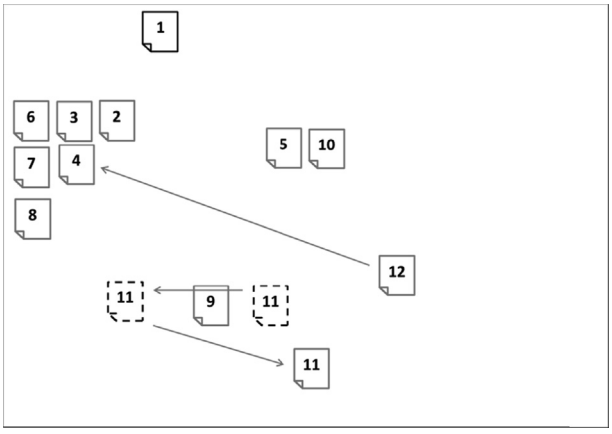

Figure 14 Post-It note map from V3 showing the movement of Post-It notes that are 'Kind of related'

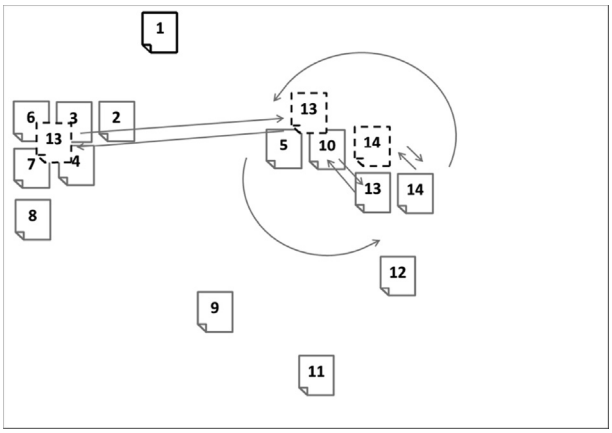

Figure 15 Post-It note map from V3 showing within category grouping

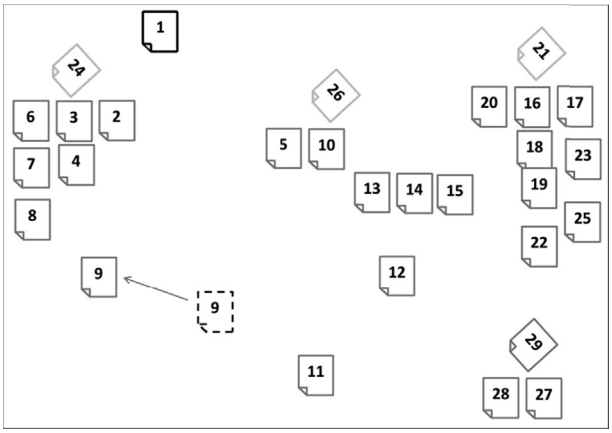

Figure 16 Post-It note map from V3 illustrating a 'Different from' relationship

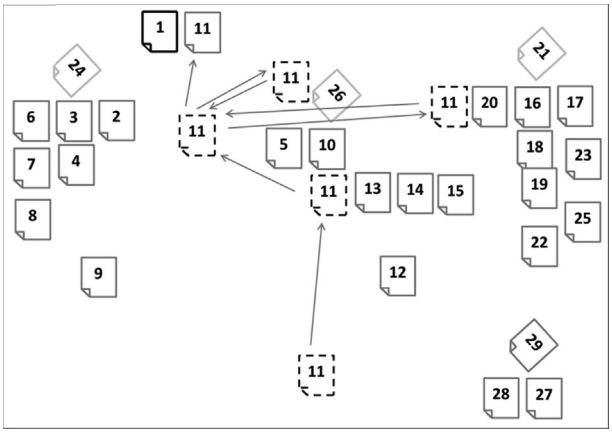

Figure 17 Post-It note map from V3 illustrating the movement of Post-It #11 which fits no category

make several observations about how Post-It notes support well-known qualities of semantic long-term memory related to categorisation.

First, in a networked understanding of semantic long-term memory, individual nodes can be more or less typical of a category based on their features or qualities, which leads to typicality gradients (Collins & Loftus, 1975). In the examples shown here, the design team's aim is to end up with a number of clearly distinct categories. However, individual Post-It notes are very often considered 'kind-of' related to the emerging Post-It clusters, and therefore not entirely typical (Figure 14). Throughout the dialogue, the degree to which Post-It notes fit into a category is expressed with phrases such as (from less to more typical): 'opposite to' (V3, 119) – 'different from' (V3, 119) – 'little bit related' (V3, 122) 'kind of related' (V3, 81), 'basically the same' (V3, 125) – 'pretty much the same' (V3, 129) – 'exactly the same' (V3, 81). The way Post-It notes are placed and moved clearly illustrates a graded structure in the relationship between individual ideas and emerging categories, as position and distance are used to indicate how typical category memberships are (Figure 15). For example, Ewan introduces his Post-It note #13 stating its connection with Post-It note #10. He then moves Post-It note #13 towards the group of Post-It notes on the left-hand side of the whiteboard, saying 'kind of an opposite to this one'. Ewan explains his point, reading the text out loud, and placing Post-It note #13 below and to the right of Post-it note #10 since it is 'kind of' related. Abby then introduces her Post-It note #14, saying it is 'a little bit related to that', so Ewan holds it up next to Post-It #13. Following this, he moves Post-It note #14 upwards to the top row of the cluster. However, he immediately moves it back down, fixes it to the whiteboard, makes a circular gesture around Post-It notes (#5,10,13,14), and says 'this is kind of the same'. In this example Ewan illustrates gradients in how typical the content of individual Post-It notes is to category membership through the distance between them.

Second, whilst clustering Post-It notes on a whiteboard easily facilitates a two-dimensional representation of emerging categories, trying to represent a third dimension becomes difficult. This problem is well illustrated when Ewan is trying to place Post It note #9 in relation to an existing cluster (Figure 16), and he states that, "It's kind of an answer element between like the next level of that one in a way". In order to indicate that this Post-It note is supposed to be understood as a next level in the hierarchy, he gestures a staircase Z-like motion below the cluster (Figure 18). Subsequently, Kenny chooses to place Post-It note #9 below and to the right of this cluster. Ewan continues to clarify the 'next level' relationship between Post-It note #9 and the emerging cluster several times, stating that the category is 'just a range (…) a spectrum' (V3, 183) (Figure 19). We find this important because our understanding of semantic long-term memory strongly suggest that categories contain hierarchical levels (Rosch, 1978). For example, the category of 'dog' may have both

Figure 18 Ewan makes a Z gesture to indicate the more nuanced hierarchy of Post-It note #9 to the cluster

superordinate levels ['animal'], and subordinate levels ['German Shepard']. Finding ways to represent this more complex structure as the categories are emerging through clustering remains a challenge. During this passage, the design team use dialogue and gesturing to augment the Post-It note representation, recognise the intended two-level meaning, and support of the intended categorical relationship.

Our third observation is that conceptual distance is a pertinent factor in the addition of new Post-It notes to the board, and that physical distance between Post-It notes is used to show conceptual difference. For example, Figure 14 illustrates how the placement of Post-It notes #5, #9 and #11 demonstrates their conceptual distinction with reference to other emerging categories. Later, as the activity progresses and the white board becomes increasingly populated, the design team try to re-position some of the lone Post-It notes into the

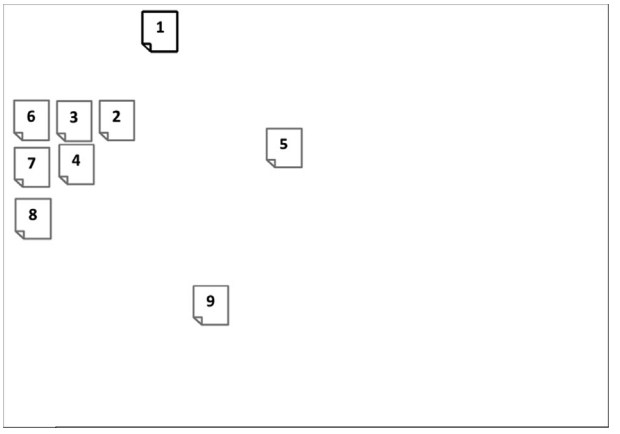

Figure 19 Post-It note map from V3 illustrating Post-It note #9 on 'the next level'

categories that have emerged. An illustrative example of this is shown in Figure 17, where the movement of Post-It note #11 is followed as Ewan moves it from category to category to try to find a fit. At one point, David suggests positioning that Post-It note #11 '*between*' two cluster categories, as it seemingly relates to both without quite fitting either. Ewan acknowledges this, and we clearly see that David and Ewan are able to interpret the relative distance of this Post-It note to each cluster in a way that suggests its semantic relationship to each of the two categories. In the end, and in order to stick to the design team's aim of creating clearly distinct categories, Abby suggests placing Post-It note #11 in a new cluster. This cluster appears to act as an idea parking lot, where the remaining individual Post-It notes without category headings get placed, e.g. Post-It notes #30-#33. Nonetheless, this example shows how Post-It note #11's placement was initially based according to the associative strength of its relationship to two distinct categories.

To summarise, it is clear that the properties of Post-It notes support qualities associated with semantic long-term memory during the clustering exercise. For example, moving to indicate membership or dissociation, and distance to indicate both within and between category associative strength. They also appear to help facilitate a process of moving from a looser category membership based on typicality gradients to the fixed categorisations that then drive the design process forward. However, we also note that visualising the nuanced hierarchical relationships within categories appeared difficult using Post-It notes on a whiteboard, and so gesturing and dialogue remain critical to supporting this process.

6 *Discussion*

The design team practice recorded in the DTRS11 dataset provides many examples of creative cognitive processes. We have considered these processes from a perspective of their being distributed across different group members, across time, and coordinated through mental and environmental structure (Hutchins, 2006). Our focus in this paper is on one particular aspect of this system of cognition, namely practices surrounding the design team's use of Post-It notes, and how these Post-It notes function as design externalisations that can support qualities associated with semantic long-term memory. Whilst we consider this to be a particularly interesting and important aspect of the processes under investigation, we also remain aware that it represents just a single factor in a wider cognitive ecology.

Alongside Post-It notes, the design team also uses a range of other tools and materials, such as spreadsheets in which they list ideas and insights, to support their design practice. The interaction of these different tools and materials, and the way cognitive resources are coordinated and shared across them, is beyond the scope of this paper. However, such a future study would help clarify some

of the issues we have raised, and improve our understanding of creative design team cognition.

Following Dix and Gongora (2011), we have investigated the design team's use of Post-It notes by considering the overlapping functions they might serve as externalisations of design ideas. We have extended this work by considering why the practice of clustering and grouping Post-It notes might be such an important and effective aspect of design activities. Our examples show that Post-It notes are referred to often in design team discussions, both as representations of single ideas and also as they are clustered to become emergent concepts. We also show that decisions are often manifested in a newly written Post-It note or through placing, moving, and organising existing Post-It notes. This highlights the importance of Post-It notes as a design material, and shows how they participate in the on-going conversation with the design situation, supporting the design team's reflection in action (Schön, 1992). Shroyer et al. (2017) have also analysed the DTRS11 dataset, and they too highlight the design team's use of Post-It notes to capture and externalise ideas during a brainstorm activity. Their analysis shows how discussion goes beyond what is actually written on the Post-it notes, and we believe this provides additional evidence for the importance of the *formational* and *transcendental* functions we discuss here.

Our analysis has shown how Post-It notes are grouped with reference to the emergence of specific concepts and themes; how through this grouping they 'evolve' into more complex forms to match and support the current stage of ideation; how they are used as objects to think with; and how they support a common understanding of the work at hand. Through this, we can see how Post-It note use scaffolds collaborative design cognition, and arguably leads to externalisations that manifest qualities associated with long-term semantic memory.

Many of these factors are supported by the characteristic properties of Post-It notes, notably their regular shape and small size, their strip of reusable adhesive, their availability in a number of different colours, and the inexpensiveness of individual Post-It notes. These characteristics mean that Post-It notes are ideal for representing individual ideas, thereby serving an *informational* function. They are also readily available, highly moveable and flexible, and can be easily discarded. This facilitates their serving *formational* and *transformational* functions. All of these characteristics also make Post-It notes ideal for grouping and clustering, and enables them to simultaneously represent individual ideas and larger concepts; and thereby serve a *transcendental* function.

Looking at these clustering and grouping activities, each Post-It note can be seen as a node in an emerging semantic network. When viewed in this way, the relative distance between Post-It notes and between Post-It note clusters

mirrors the associative strength between the individual ideas and conceptual categories they represent; and the different functions Post-It notes serve overlap. For example, Post-It notes in a developing cluster must simultaneously be *informational* with regard to the individual ideas they represent, and both *formational* and *transformational* with regard to the developing semantic network; and as the design team recognise the semantic structures emerging, the *transcendental* function Post-It notes can serve is also clearly evident. With this finding, we add a new dimension to literature describing how materials may support design cognition; by considering convergent design tasks rather than the generative, emergent or divergent aspects typically covered in past research.

Finally, we note how the design team would maintain these externalisations of their design ideas by transporting and reusing the same clustered Post-It notes across sessions held in different places and at different times. However, in order to do so they would sometimes first remove all the Post-It notes and then reposition them onto a new board for transportation. Whilst they would carefully maintain the overall cluster structure, they would not necessarily recreate exactly the particular relative associations between individual Post-It notes, or within and between clusters. We also note that relationships between individual Post-It notes, both within clusters and between clusters, and between clustered groupings of Post-It notes, were not typically referred to in terms of degrees of association. More commonly, a Post-It note would be referred to as either belonging or not belonging to a cluster or category. This indicates that the support Post-It notes were providing for nuanced and graded categorisation was primarily local and situational within the process of forming clusters, and that the value across sessions was in the resulting non-graded clusters.

With this study we have begun to explore different functions that Post-It notes might serve during creative design team practice. Future investigations might go beyond this and examine in detail how Post-It notes are used in conjunction with other design materials, including digital resources such as spreadsheets containing ideas and observations. Further research is also needed to more clearly determine the relationship of Post-It note clustering to the qualities of semantic long-term memory. However, it seems evident that the activities we examined in the DTRS11 dataset would be very different without the humble Post-It note.

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