How sketching can affect the idea generation process in design group meetings

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This study consists of four experimental idea generation meetings, which explore whether functions of sketching in design activity are also valid for idea generation meetings.

The relevant functions of sketching found in theory are: 1) supporting a re-interpretive cycle in the individual thinking process, 2) supporting re-interpretation of each other's ideas in group activity, and 3) enhancing access to earlier ideas. To examine these three possible functions of sketching activity in a group, a model is introduced that considers sketching activities as interactions with the group's external memory. In each meeting both a technique that includes sketching and a technique that includes writing as the primary mode of communication was applied. Differences in the participants' linking behavior for these two techniques were compared. The results provide some support for the first and the third functions of sketching. No support was found for the second function.

Keywords: collaborative design, creativity, design cognition, drawings, problem solving

Idea generation techniques, like brainstorming, are commonly applied by designers as a means to come up with original design ideas. In the existing body of idea generation techniques, the primary mode of expressing ideas is in written language. Usually, during idea generation meetings, brief descriptions of ideas are listed on a flipchart. In contrast, when involved in unstructured design meetings, designers tend to make extensive use of sketching when generating design ideas. Design thinking researchers regard this activity of sketching as a means to spur creative thought. Many lines drawn in

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a sketch are incomplete and can be interpreted in different ways. This is referred to as 'ambiguity' or 'indeterminacy' (Goel, 1995), which enables designers to re-interpret what they have just drawn, and to proceed designing with the newly acquired insights. The interaction that designers have with their sketches is seen as essential to creativity in design activity (Purcell and Gero, 1998).

In the creative problem solving literature, these creative qualities of using sketching are much less emphasized. In his categorization of active ingredients in idea generation techniques, Smith (1998) presents the use of making graphic representations of the ideas as a 'display stimulation tactic'. He mentions: 'Presumably, when visually depicted, ideas are more able to inspire new ones' (p. 125). Granted that this may also be a valid function of a designer's sketching, it does not cover the creative functioning of sketching as found in the design thinking research literature.

The objective of this paper is to explore whether the functions of sketching as proposed in design thinking research can also be relevant for idea generation meetings. If this is the case, utilizing these functions may enrich creative problem solving activity. First, we will describe the functions of sketching in design activity and how they may be applicable for idea generation meetings. To examine these three possible functions of sketching activity in a group, a model is introduced that considers sketching activities as interactions with the group's external memory. Then we will describe the research method used, called 'linkography', with which we take a process perspective: investigating the qualities of the connections between the ideas, rather than the qualities of the resulting ideas themselves. Next, we will discuss the results of an experimental study, which consists of four idea generation meetings in which both graphic and written language are used as a means for idea notation. In the final remarks, we will address some limitations to this research, suggestions for further research and suggestions for developing idea generation techniques that involve sketching.

1 Functions of sketching in design

In his book 'Engineering and the mind's eye', Ferguson (1992) identifies three kinds of sketches, which may be useful for identifying the role of sketches in creative design groups: the thinking sketch, the talking sketch, and the prescriptive sketch. *Thinking sketches* refer to the designers making use of the drawing surface in support of their individual thinking processes. According to Ferguson, engineers use the thinking sketch 'to focus and guide nonverbal thinking' (p. 97). *Talking*

sketches refer to designers making use of the (shared) drawing surface in support of the group discussion. Ferguson states: '…talking sketches, spontaneously drawn during discussions with colleagues, will continue to be important in the process of going from vision to artifact. Such sketches make it easier to explain a technical point, because all parties in the discussion share a common graphical setting for the idea being debated' (p. 97). *Prescriptive sketches* refer to the designers communicating design decisions to persons that are outside of the design process. Ferguson describes the prescriptive sketch as the means for the engineer: 'to direct the drafter in making a finished drawing' (p. 97).

The prescriptive sketch is, according to McGown and Green (1998), '…used almost exclusively within the latter detailing (pre-manufacture) phases of the design' (p. 436). The prescriptive type is not very relevant for this study as we are interested in the functions of sketching in conceptual design activity. Ullman et al. (1990) propose an additional use of drawing in the design process. Ullman et al. state that the first use of the act of drawing is to 'archive the geometric form of the design' (p. 264). Sketches provide a means to store design ideas, so that they can be revisited at a later point in time. We will refer to this category of sketches as 'storing sketches': *Storing sketches* refer to the designers using the drawing surface to archive design ideas for their own future reference. Storing sketches have much in common with prescriptive sketches. They both freeze, rather than develop, design ideas. However, the purpose of these two types of sketches is quite different. The storing sketch is intended for retaining information, whereas the prescriptive sketch is intended for communicating information.

Relating to the different kinds of interactions that designers have with their sketches, these three types of sketches – thinking, talking, and storing – serve as an initial categorization to help organize theories on the functions of sketches found in design thinking literature.

1.1 The thinking sketch

In a review of the research on drawing and design, Purcell and Gero (1998) focus on the role of sketching in design cognition. This research is mainly concerned with investigating the ways in which the activity of sketching stimulates creativity in design cognition. They point out underlying themes regarding the role of sketching in design. The principal theme deals with the positive role that sketching plays in re-interpretation. A second theme is that re-interpretation provides new knowledge and that this new knowledge leads towards further re-interpretation. Various researchers propose such cyclical models of

re-interpretation, each with a slightly different connotation, ranging from a dialectic type of argumentation between *seeing-as* and *seeing-that* (Goldschmidt, 1991), interactive *conversations* with the paper on which the designer draws (Schön and Wiggins, 1992) and movement from *description* to *depiction* (Fish and Scrivener, 1990). In order to provide a general understanding of this re-interpretative process, these various perspectives will be described briefly.

Goldschmidt (1991) observes that architectural designers produce unclear, ambiguous sketches. She suggests that this is a substantial component of creativity in the design process. Designers often use sketches as metaphors for the objects to be designed. She calls this *interactive imagery*, which she defines as:

…the simultaneous or almost simultaneous production of a display and the generation of an image that it triggers. Sketching, then, is not merely an act of representation of a preformulated image; in the context we deal with, it is, more often than not, a search for such an image. (p. 131)

She proposes a dialectic type of argumentation in design. Based on protocol studies Goldschmidt points out that, while making idea sketches, architects use two types of reasoning in rapid oscillation. One type is based on analogical or metaphorical thought, dealing with extracting new meaning from the sketch. She describes this kind of reasoning as seeing-as. The other type, seeing-that, deals with the design consequences of this newly acquired meaning of the sketch.

Schön and Wiggins (1992) observe that designers develop their products by engaging in an interactive conversation with the paper on which they draw. They describe design as a cyclical process of sketching, interpreting and taking the sketches further. According to them:

Working in some visual medium — drawing, in our examples — the designer sees what is 'there' in some representation of a site, draws in relation to it, and sees what has been drawn, thereby informing further designing. In all this 'seeing', the designer not only visually registers information, but also constructs its meaning — identifies patterns and gives them meaning beyond themselves. (p. 135)

Another function of sketching, identified by Fish and Scrivener (1990), is that sketching facilitates the transition from general descriptive knowledge into specific depiction. According to Fish and Scrivener the primary reason for designers to sketch is: '…the need to foresee the results of the synthesis or manipulation of objects without actually executing such operations' (p. 117). In order to explain the functioning of sketching within design, the authors present a spectrum of visual

representations, ranging from purely descriptive symbol systems to purely depictive symbol systems. Descriptive symbol systems can represent whole classes of information: they are abstract and categorical. An example of a descriptive symbol system is natural language. For instance, the word *chair* may represent many different types of seats; sofas, office chairs, TV chairs, rocking chairs, and garden chairs are all covered under the label *chair*. The information in such a descriptive symbol system is extrinsic, meaning that the object described by the symbol system is associated with the descriptive system solely by means of external definitions. The word *chair* does not contain any of the qualities of the represented objects, neither in structure, color, nor in form. On the other side of the spectrum are depictive symbol systems, which carry all information about the represented objects within themselves, and do not depend on rules for extracting the information from the representation. These symbol systems are concrete and spatially specific, meaning that there is a direct relationship between the spatial position in the medium and the spatial position in the object represented. For instance, a picture of a rocking chair contains the topological information of that object. Depictive representations refer to specific objects, rather than classes of information.

According to Fish and Scrivener, sketches have a special set of attributes that help the human mind in translating descriptive propositional information into depictive information. They theorize that in a creative design process this depictive information is then scanned, which leads to new descriptive propositional information, which in turn may be translated into depiction, and so on:

We posit that sketches have the important function of assisting the mind to translate descriptive propositional information into depiction. This depictive information may then be scanned by attentional processes to extract new and perhaps original descriptive information, which in turn can lead to new depiction. (p. 118)

These theories provide two general roles of sketching within the designer's individual process that need to be considered when investigating sketching in idea generation meetings in product design. First, sketching is said to allow for tentative and non-committal moves from general description towards specific depiction. Second, sketching is said to involve a cyclical process of re-interpretation. The first role is likely to be more relevant for the later phases of an idea generation process, in which a higher level of resolution is desired. Especially the second role could be relevant for idea generation meetings, as the general goal of such meetings is to provide a variety of novel ideas.

1.2 The talking sketch

In addition to the individual, cognitive functions of sketching, typical group functions can be identified. The literature on the typical group aspects of sketching is less elaborate than the literature on individual functions and consists mostly of reports of exploratory investigations. The main efforts for understanding group design are related to design communication, predominantly connected to furthering the field of computer supported collaborative work (CSCW) and human–computer interaction. The principal interest of this field of research is to allow designers to work together from different locations, by means of computer support. As computers constrict the communication lines available, most research approaches focus on understanding the workspace activity of design groups (Tang and Leifer, 1988; Tang, 1991) and experiments which involve limiting the communication lines available (Bly, 1988; Scrivener and Clark, 1994). The recognized importance of interaction through sketching and gesturing activity lead to preliminary CSCW solutions, which show, for instance, the hand of the person drawing (Bly, 1988), in addition to the drawing.

One of the topics of interest within the research field of human–computer interaction is the role of the 'shared visual context' in communication (Karsenty, 1999). In a design discussion, the shared visual context can be used to make relative references, for instance: 'let's combine *this* with *that*', rather than to describe the whole idea when referring to it. This way, relative references provide a more efficient communication process. In design communication, the use of quickly drawn sketches in support of group discussions could lead to a more efficient design process by providing a shared visual context.

In addition to providing a shared visual context, Scrivener and Clark (1994) suggest a second role for sketching in collaborative design. In relation to the way in which sketching supports creative group discussion they observe:

The fact that drawings are usually accompanied by verbalizations (in the case of the individual designer this would just be unspoken thought) supports the idea that sketches only partially represent ideas in mind. In general, a drawing act in sketching is not an attempt to represent a solution as such, rather it is a notational device that helps its creator to reason with complex and labile mental structures. (p. 114)

According to Scrivener and Clark, sketching provides representations of design solutions that allow for a range of interpretations of elements. By

sketching, temporal decisions are made which allow for evaluation and interpretation of a design solution, without excluding alternatives.

Finally, besides having the function of communicating and discussing ideas through sketches, the act of sketching itself is regarded important in team design activity. Tang (1991) points out the distinction between the information contained in the artifacts that result from design sketching activity and the information within the activity itself. Relating to his observations from protocol analysis of eight experimental design team meetings, he concludes: 'The process of creating and using drawings conveys information not found in the resulting drawings' (p. 150). According to Tang, the act of sketching is a means of communication and attracting attention, as well as providing a medium for storing information.

As with the individual functions of sketching, the function of inviting re-interpretation is especially relevant for the idea generation process, as re-interpretation can lead to novel directions for generating ideas.

1.3 The storing sketch

As we mentioned earlier, Smith (1998) refers to this function when he states: 'Methods implementing the *Display* tactic make ideas visible in a graphic array. Presumably, when visually depicted, ideas are more able to inspire new ones' (p. 125). According to McKim (1980) building and maintaining a – what he calls – 'visible graphic memory' (p. 127) fosters the group's creative process by providing an easily accessible database of generated information, which stimulates building on earlier ideas. So, in relation to the storing sketch, sketching may facilitate archiving and retrieval of information generated earlier in the problem solving process.

In the design thinking research literature little relevant information can be found concerning this function of sketching. However, in the field of visual cognition, differences in recognition of words and pictures have been the subject of investigation. This research is relevant for our search, if we consider a sketch to be a type of picture.

There is evidence that pictures of objects can be categorized more rapidly than words that describe these objects (Potter and Faulconer, 1975). But, if the objects from the different categories share many physical characteristics, this advantage of pictures over words may be lost. In that case, categorization for pictures may even be slower than for words (Snodgrass and McCullough, 1986). This relates to the depictive qualities of sketches: by sharing actual attributes of the (imaginary or

real) object they refer to, sketches provide stronger distinctive features than words. Humphreys and Bruce (1989) hypothesise:

Words representing a particular class of objects will generally bear no greater resemblance to one another than words representing objects from different classes. This is not true for most objects (though there may be exceptions, such as faces). Objects from many natural classes resemble one another more closely than objects from other classes (e.g. many animals resemble one another, as do birds, insects, etc.). It may be that visual processing capitalizes on these family resemblances to optimize cognition. (p. 285)

Other than a few exceptions, words do not share attributes with the actual object that they represent, which means that words lack distinctive features. As sketches are more easily recognized among other sketches, they facilitate the designers' access to earlier ideas. Easier access to earlier design ideas is likely to stimulate increased use of these earlier design ideas. So, sketches may enhance the use of information in previously generated ideas by facilitating the access to these ideas.

To summarize the literature findings we propose the following potential functions of sketching in idea generation meetings:

- In relation to the *thinking* sketch: Sketching stimulates a re-interpretive cycle in the individual participant's idea generation process.
- In relation to the *talking* sketch: Sketching stimulates the participants to re-interpret each other's ideas.
- In relation to the *storing* sketch: Sketching stimulates the use of earlier ideas in the idea generation process by enhancing their accessibility.

2 *Sketching as interaction with external memory*

In the previous section, the various functions of sketching found in theory were organized by means of an adaptation of Ferguson's (1992) categorization of types of sketches. Even though the thus derived categorization worked for structuring the functions of sketches found in the design literature, there are two problems with it, which limit its use for developing a coding scheme for differentiating between the different functions in an empirical study.

First, if we want to compare the idea generation processes when sketching or written language is used as a working medium, the categorization used needs to refer to various aspects of the use of

notations in the group, regardless of the working medium used. Ferguson's categorization only refers to sketching as a working medium and does not allow for inclusion of writing as a working medium.

Second, Ferguson's classification describes sketches in terms of types of artifacts, which suggests unchanging characteristics. Ferguson labels his types by means of the kinds of activity that they are used for, such as the thinking sketch. In practice, a single sketch may very well have different functions at different times. For instance, a designer may produce an idea sketch individually. At this point the sketch can be largely considered to be in support of the designer's own cognitive process. In Ferguson's terms, this is a thinking sketch. Then, when the designer explains his or her idea, the sketch is used to support the explanation of the idea. All of a sudden the thinking sketch turns into a talking sketch. Then, the sketch may be pasted on the wall and the designers shift their attention to producing new idea sketches. At this point the talking sketch turns into a storing sketch. So, in this common example of group idea generation activity, a single sketch needs to be categorized as three different types at different times. If a single sketch is likely to have different functions in various activities, it may be more informative to develop a categorization that addresses the designer's different kinds of interaction with the working medium, rather than providing a categorization of types of sketches.

As we are more interested in differences in the transfer of information that takes place through the working media, rather than the differences of the resulting artifacts, it may be useful to take an information processing perspective for describing the different connections that the groups make with their earlier ideas. Then, the designers' interactions with their working media can be regarded as interactions with the group's 'external memory'. The group's external memory consists of all the task-related notations made by the group members and that are available to them. In idea generation meetings, the external memory can be considered to consist mainly of the posted flipcharts with ideas and the participants' individual notebooks or post-it pads.

We based this categorization largely on Newell and Simon's (1972) division of external memory into short-term areas and remote areas. Newell and Simon make a distinction between external memories that are in the direct view of the subject, which the above refers to, and more distant external memories which require more effort to access:
There are, of course, more remote EM's, such as the work sheet on the side of the table, the sheet under the sheet now being worked on, nearby

books, books in the library, and so on. Accessing times become increasingly large as more extensive motor behavior and physical distance are involved in retrieval. (p. 802)

For our categorization for interaction with the working medium in idea generation groups, this means that a distinction needs to be made between the short-term and the remote parts of the designer's external memory. The short-term part is used in the immediate idea generation activity. This is, what Newell and Simon refer to as the extension of short-term memory, which consists of the information that is in the designer's direct field of vision. The remote part of external memory consists of information that is outside this field of vision.

The term short-term suggests a relation to time rather than to the location of the idea, which could be confusing if we apply this term to external memory, in which the immediate area is identified by the location of the idea. To avoid confusions, we will use the term 'direct' external memory, rather than 'short-term' external memory to refer to the ideas that are immediately available to the designer.

This model of a designer's interaction with notations in his or her external memory can be extended towards group problem solving. Interaction between group members takes place through verbal or gestural communication, and through the group's external memory. The group's external memory consists of the combined external memories of the individuals. Some parts of the group's external memory belong to the individual group members, for instance, notes written by a group member in a personal notebook. Other parts of the group's external memory are shared, for instance, when a group member makes marks on a whiteboard while the other group members are watching. Then, this information becomes available to all group members present. Analogous to the individual parts, the shared parts of the group's external memory can be sub-divided into direct parts and remote parts. The shared-direct parts of the group's external memory may consist of notations that are made in support of the discussion on a whiteboard, or the flipchart used by a facilitator to record options while brainstorming. The shared-remote parts of the group's external memory may consist of notations on flip charts that are posted away from the direct view of the group members. Figure 1 shows the four parts of external memory available to a group member. Arrows refer to the ways in which information can move between the various areas.

This model provides a categorization of four link types that reflect the different interactions of a design group with their notations in external

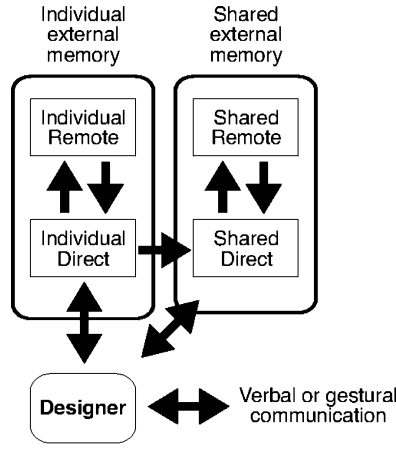

Figure 1 Model of the various parts of external memory available to a group member

memory. Interactions with the individual-direct area refer to the thinking sketch. Interactions with the shared-direct area refer to the talking sketch, and interactions with the individual-remote and shared-remote areas refer to the storing sketch. Figure 2 positions the three functions of sketching found in the design thinking literature within the model of the group's external memory.

3 Method

3.1 Procedure

A technique called 'brainsketching' (Van Gundy, 1988; Van der Lugt, 2002) was used as a representative of idea generation techniques that use sketching. Brainsketching is a graphic variation of the more widely

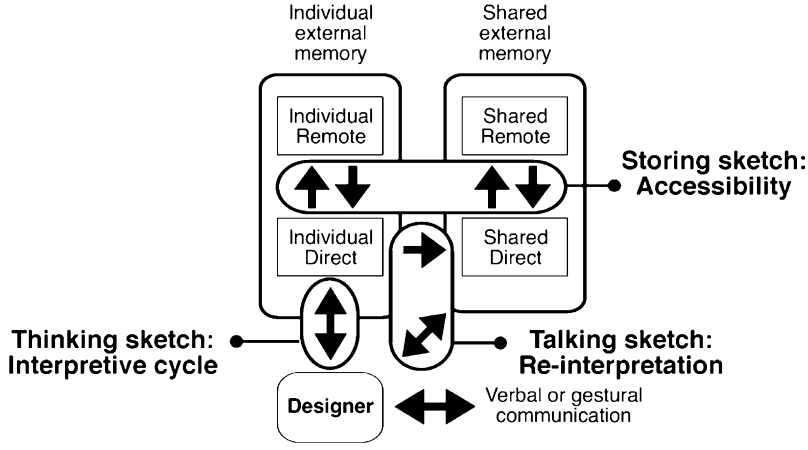

Figure 2 Theoretical functions of sketching

known brainwriting technique (Geschka et al., 1973). During brainsketching, participants sketch ideas individually in short rounds. After each round they briefly share their ideas and switch papers. In the next round they use the ideas already present on the worksheet as a source of inspiration. Usually this procedure is repeated about five times.

Selecting brainsketching as a representative of graphic idea generation techniques suggests choosing brainwriting as a representative of sentential idea generation techniques, as brainsketching is a direct graphic variation of the brainwriting technique. However, brainwriting tends to result in very high numbers of ideas with little variation among the ideas (Gryskiewicz, 1980). Isaksen et al. (1998) suggest using brainwriting when a very high number of ideas within a few themes are required. Thus, brainwriting is not exemplary for the class of associative idea generation techniques that use writing. As our objective is to gain an understanding of the differences in process characteristics between idea generation techniques that use sketching or writing, it is more suitable to slightly compromise on comparability, because it is more useful to investigate techniques that are typical for their mode of representation. Therefore, the brainsketching technique was compared to brainstorming with post-its (Isaksen et al., 1998), which was selected as a representative of idea generation techniques that use writing as the primary working medium. Brainstorming with post-its is a slight variation on the brainstorming technique (Osborn, 1953), developed to increase the speed of recording ideas. During brainstorming with post-its, group members generate ideas by writing them down on large post-its in a clear and legible manner. After having written down an idea, a group member explains the idea to the group and then hands the post-it with the idea to the facilitator. The facilitator then pastes the idea onto a flipchart. According to Isaksen et al. (1998), brainstorming with post-its is likely to result in the same types of options as would be generated by regular brainstorming.

In each of four experimental meetings both brainsketching and brainstorming with post-its were applied which allowed us to perform a paired comparison analysis of each participant's problem solving behavior ($n = 20$). Each meeting consisted of five advanced product design students who were involved in a course in facilitating creative problem solving meetings. Each meeting was moderated by an experienced professional creative problem solving facilitator.

The participants were asked to generate ideas for products to make traveling by car fun for children. The assignment involved generating ideas for a particular multi-functional family car.

3.2 Method of analysis

The main reason for organizing a creative group meeting is for the group members to interact in their problem solving efforts. This makes the 'building on each other's ideas' guideline for divergent thinking (Osborn, 1953) especially relevant to this research project. Investigating the ways in which the participants build on each other's ideas provides direct process clues regarding the functioning of the techniques applied. Linkography (Goldschmidt, 1996; Goldschmidt and Weil, 1998) is a research approach which specifically addresses the ways in which designers build on each other's input. We have adapted this method for application in our research of creative problem solving meetings. In this article we cannot go into detail regarding the linkography approach. For a more detailed description we refer to earlier work: Van der Lugt (2000, 2001). Here we will limit ourselves to a brief description of the general approach, followed by a more in-depth description of the categorization of links needed in the current study.

In linkography for each idea direct connections or 'links' with all earlier ideas are determined by gathering and evaluating evidence of connections. Evidence can be found within the content of the ideas. Such evidence is based on finding similarities in subject matter. Evidence can also be found within the context in which the ideas are generated. Such context indicators can consist of among other things: gestures or remarks made by the designers when they explain their ideas; physical action when conceiving the idea; or connecting symbols on the flipcharts (Van der Lugt and Van der Graaf, 2002). We believe that making explicit use of context indicators while constructing link systems enhances the reliability of linkography as a research method.

For each of the four brainsketching segments and the four brainstorming segments, this process of determining links was performed twice by the same person with a time interval of at least one week. For each segment, the discrepancies between the two link systems were then re-evaluated, which provided the final link system. For verification purposes, an independent judge was asked to fill out a link system for two of the segments. Inter-rater agreement was determined using Cohen's Kappa. Good levels of agreement were found ($K = 0.73$ and $K = 0.63$) between the link systems produced by the two raters.

3.3 Categorization of links as interactions with external memory

Once the link systems were finalized, the links were categorized to reflect structurally different interactions that the designers can have with their earlier ideas.

Within a link system, *link densities (l.d.)* can be determined for these various parts of the group's external memory, which provide indicators for the extent to which brainstorming and brainsketching make use of these different parts. The link density consists of the number of links made within one area of external memory, divided by the number of ideas generated.

The distinction between the individual and the group aspects of the external memory can easily be identified in a link system. An 'individual' link is marked when an idea has a connection with an earlier idea by the same designer. A 'shared' link is marked when an idea has a connection with an earlier idea generated by another designer.

An operationalization for the distinction between the direct and the remote aspects still needs to be made. Newell and Simon's (1972) working definition of the external part of the short-term memory is 'the part of the visual display that is in the subject's foveal view' (p. 801). But on the same page, they doubt their assumption: '…it is not clear whether only the instantaneous foveal region can be merged with STM or whether a somewhat larger region, connected by adequately indexed saccades, might be available' (p. 801). In any case, direct interactions with external memory can be assumed to take place with ideas that do not have to be searched for. These are the ideas that are present within the focus of attention.

For the brainsketching segments, the immediate linking area can be considered to contain the ideas that were explained just before the current round of generating ideas started, plus the ideas that the designer is generating him- or herself during the present round of sketching ideas. See Figure 3 for the resulting representation of the link system, which we refer to as a 'link matrix'. In the figure, links in the shaded areas represent interaction with the direct part of external memory. Black squares refer to interpersonal links and crosses refer to self-links.

During brainsketching, the designers individually generate ideas in parallel. Therefore, it is not likely that there are direct links between

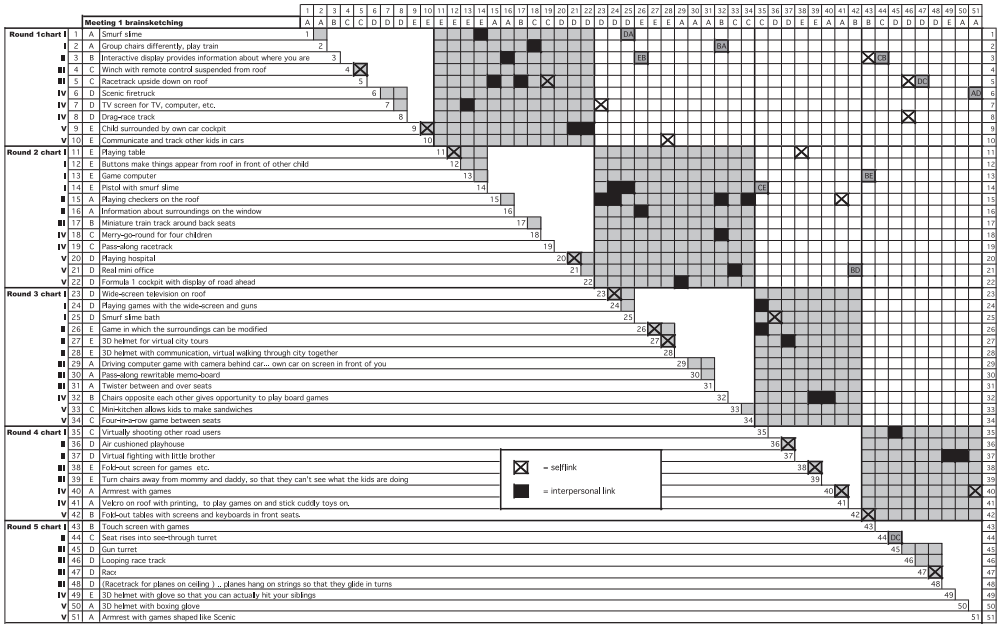

Figure 3 Link matrix for a brainsketching segment

ideas generated by different designers within the same round of generating ideas. The designers may sometimes take a quick look at the flipcharts of their neighbors, but this was found to occur rarely. In the brainsketching link matrices the areas where linking is unlikely to occur are whitened. Of course, within each round of generating ideas, designers can build on their own recently generated ideas, as represented by the single links, or small triangular groups of potential link locations at the diagonal of the link matrix.

For brainstorming with post-its the generation of ideas is a continuous group process, which makes it more complicated to provide an operationalization for the direct linking areas in the link matrix. As for brainsketching, the direct linking area ought to cover the link locations with ideas that are still present in the focus of attention. This number needs to be more than seven, because according to Miller (1956) that is the average amount of ideas or chunks that the internal short-term memory can contain. The external notations are supposed to provide an extension to the short-term memory and therefore should contain more than these seven ideas. It cannot be much more than seven ideas, however, because the human attentional focus can only cover a limited number of items (Pashler, 1995). We made the assumption that

the direct linking area for the brainstorming segments contains the link locations with the 10 previous ideas. The actual direct area may contain a few ideas more or a few ideas less, but the results do not change dramatically when the bandwidth is made a few link locations narrower or wider. See Figure 4 for an example of a link matrix for a brainstorming with post-its segment.

For each of these four categories of links, the *link-type indices (LTI)* were determined. The link-type indices (Supplementary, Modification, and Tangential) provide the distribution of different types of connections that are made within the external memory area, based on a categorization of the nature of ideas provided by Gryskiewicz (1980). Tangential links indicate wild leaps into a different direction, modification links indicate direct variations and supplementary links indicate small alterations and repetitions.

4 Results

For our investigation of the functions of sketching in idea generation meetings especially the differences in link density and tangential link-type index for the brainstorming and brainsketching conditions are of interest. Table 1 shows the results for each area of external memory. With these results, we can now evaluate whether the three basic functions of sketching in design activity as proposed before – are also valid for idea generation meetings.

4.1 The thinking sketch

Individual idea generation has a substantial role in the brainsketching process. Compared to brainstorming, ideas had significantly ($p < 0.005$) more connections with ideas in the individual-direct area of the external memory (link density for brainsketching, $x = 0.26$, SD = 0.13; for brainstorming, $x = 0.12$, SD = 0.10).

The purported function of sketching in idea generation groups is that the re-interpretation taking place in an idea sketching cycle is said to be conducive to creativity. Purcell and Gero (1998) describe such re-interpretation as: 'the emergence of new ways of seeing the perceptual (drawn) representation of a potential design' (p. 396). Suwa and Tversky (1997) relate re-interpretation to '… acts of shifting the focus of attention' (p. 394). For idea generation meetings, such 'new ways of seeing' or 'focus shifts', can contribute to the creative process by opening up new directions for further exploration. The level of tangential linking can be seen as an indicator for such creative

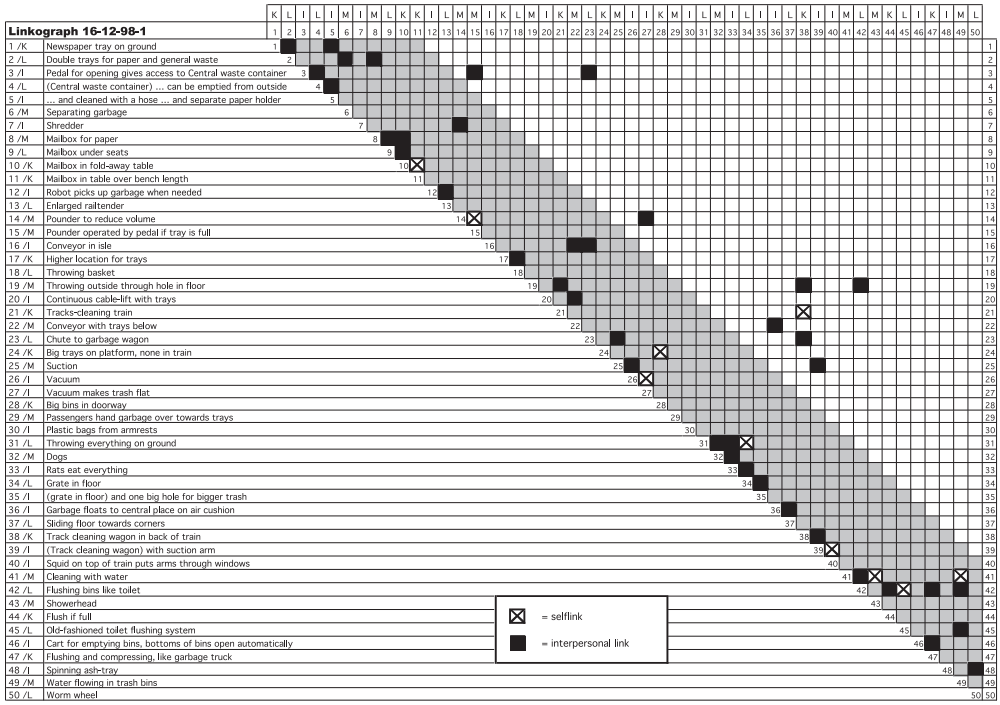

Figure 4 Link matrix for a brainstorming segment

re-interpretation taking place. Tangential links indicate possible focus shifts, which may be further explored through direct association, identified by modification-type linking, and steps of incremental development, identified by supplementary-type linking.

So, a relatively high ratio of tangential links can be seen as a basic indicator that the working medium used supports creativity through re-interpretation. A comparison of the link-type indices in the individual-direct area of external memory between the brainsketching and brainstorming conditions does not show a substantial difference in tangential-type links. For the brainsketching segments, the tangential link-type index was only slightly higher ($x = 0.50$, SD = 0.04) than for brainstorming ($x = 0.46$, SD = 0.20). However, by comparing the link-type indices for the area of external memory at hand − the individual-direct area − with the overall link-type indices, we can evaluate the relative contribution to the creative process of the proposed individual re-interpretive cycle. The link-type indices for the links with ideas in the individual-direct area provide a rough indication for the nature of this part of the process.

Table 1 Results

		Brainstorming	Brainsketching
Individual direct	l.d. (SD)	0.12 (0.10)**	0.26 (0.13)**
	LTI_T (SD)	0.46 (0.20)	0.50 (0.04)
Individual remote	l.d. (SD)	0.09 (0.09)	0.13 (0.12)
	LTI_T (SD)	–	–
Shared direct	l.d. (SD)	0.43 (0.17)	0.53 (0.22)
	LTI_T (SD)	0.41 (0.04)	0.29 (0.06)
Shared remote	l.d. (SD)	0.20 (0.18)*	0.35 (0.22)*
	LTI_T (SD)	0.12 (0.14)	0.25 (0.05)

For the individual-remote area, too few data entries were found to determine reliable link-type indices.The significance of the difference in means was determined by means of a paired sample *t*-test (two tailed). $*p < 0.05$, $**p < 0.005$.

In the individual-direct area of the brainsketching segments, a relatively high ratio of tangential linking takes place ($x = 0.50$, SD = 0.04), compared to the overall tangential link-type index ($x = 0.32$, SD = 0.15). This indicates that in the individual-direct area of external memory a high ratio of wild leap-type connections is made with earlier ideas, which means that the linking in the individual-direct area stimulates creativity by opening novel directions.

4.2 The talking sketch

Similar to the previous individual direct function of sketching, the link-type indices for the shared-direct area provide some insight into the nature of the connections made with the recently generated ideas of other designers. For both brainstorming and brainsketching the shared-direct area is an important source for making connections (link density for brainsketching $x = 0.53$, SD = 0.22; for brainstorming $x = 0.43$, SD = 0.17).

As in the previously mentioned function of sketches for the individual design process, if sketches stimulate creativity through inviting re-interpretation of each other's sketches, this should show by a relatively high ratio of tangential links for the brainsketching condition in this area. However, the tangential link-type index is substantially lower for brainsketching ($x = 0.29$, SD = 0.06) compared to brainstorming ($x = 0.41$, SD = 0.04). This is not in line with what one would expect if the creative process were influenced by the proposed function of the designers re-interpreting each other's idea sketches.

4.3 The storing sketch

Because sketches may be easier to identify in the external memory, the designers are more likely to make use of the ideas in the remote area of

external memory, which consists of the individual-remote area and the shared-remote area. Comparing the link densities in these areas of external memory for the brainsketching and for the brainstorming condition provides a basic indication of whether this function of sketching is relevant for idea generation meetings.

The designers made few connections with ideas in the individual-remote area of external memory in both conditions. And, there is no substantial difference between the link densities for the individual-remote area (for the graphic condition: $x = 0.13$, SD = 0.12; for the sentential condition: $x = 0.09$, SD = 0.09).

Many more connections are made with the shared-remote area. Here, there is a substantial difference between the link densities. The mean link density in the shared-remote area for the graphic condition ($x = 0.35$; SD = 0.22) is significantly ($p < 0.05$) higher in comparison to the sentential condition ($x = 0.20$, SD = 0.18). Thus, in the sketching condition, ideas have many more connections with ideas in the shared-remote part of external memory, which supports the notion that brainsketching enhances the creative group process by improving the accessibility of each other's earlier ideas.

5 *Conclusion*

So, does sketching support creative process in idea generation groups? The results endorse this notion for two of the three proposed functions of sketching in idea generation groups, relating to the thinking sketch and the storing sketch. The results do not support the function that relates to the talking sketch, which suggests that sketching stimulates creativity by inviting re-interpretation of each other's idea sketches.

So, in idea generation groups, sketches can stimulate creativity, especially in the immediate individual idea generation process, by providing new directions for idea generation in an individual generate-interpret cycle. And, sketches can provide a more integrated group process, by providing better access to the earlier ideas, especially in the shared parts of external memory.

6 *Final remarks*

The two techniques applied in the experimental meetings are rather different in nature. Brainsketching involved an idea generation process in rounds, whereas brainstorming involved a continuous idea generation process. This means that no generalizations can be made about the functioning of sketching in idea generation meetings; the implications

are limited to the differences found between the two techniques. Because of the results of an earlier study (Ullman et al., 1990) we could not use an experimental design in which only the working medium was altered. This earlier study showed a breakdown of the idea generation process, if sketching was included in brainstorming, without making structural changes to the technique.

The individual function of sketching – relating to the thinking sketch – particularly accounts for the way in which the so-called 'visual brainstorming' technique failed in this earlier study. Visual brainstorming was a direct variation to brainstorming with post-its. Designers were asked to sketch ideas on individual sheets of paper and, when done with a sketch, immediately share the idea with the group, whereupon the facilitator pasted the sheet with the idea sketch onto the flipchart. This technique did not allow for the individual idea generation cycle, in which new search directions can be found. Indeed, the technique not only lacked quantity of ideas (only 17 ideas were generated, compared to 46 for the control condition, in which regular brainstorming was applied), but the tangential link index was also especially low for visual brainstorming ($x = 0.21$, compared to $x = 0.46$ for regular brainstorming), indicating few new connections that could open up novel directions for generating ideas.

Apparently, even when involved in an idea generation meeting, participants need to be allowed – and perhaps to even be stimulated – to engage in individual cycles of re-interpretation. The brainsketching technique applied in the current study accomplishes this by means of formal rounds of individual idea generation. Perhaps other ways are possible in which the participants can make more informal shifts between the re-interpretive cycle of their individual sketching process, and making connections within the group process.

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