IS SKETCHING AN AID TO MEMORY OR A KIND OF THINKING?

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Abstract: Reading the sketching in design literature gives the impression that designers are cruelly crippled by cognitive disabilities and limitations that can only be surmounted with the aid of external memory devices, such as sketches and drawings. Designers are not disabled so, not in general. Sketching is not an essential aid to memory, as is widely presumed. Sketching is a kind of thinking that is needed in designing. An argument is presented to support this answer that draws on work by some of the authors who presume sketches to be cognitive aids.

1. Introduction: Cognitively Disabled Designers

Reported research on sketching and drawing in design is dominated, explicitly or implicitly, by a view that presumes sketching to be a needed aid to memory or mental imagery. Chandrasekaran (1999), in his opening paper to the Visual and Spatial Reasoning in Design conference held in 1999 (VR99), says that

“... Certainly one of the roles of external representations is as memory aid.”

And he suggests that they are needed because

“... Mental images are rather weak, in comparison with external representations, in their ability to support perception of new objects...”

Further on, in the same paper, Chandrasekaran adds that

“... In addition to this obvious role of external representations as memory aids, the representations are generally helpful in supporting inference.”
Tversky (1999), again in a paper presented at VR99, tells us that

“... Drawings are a kind of external representation, one of many cognitive tools invented to facilitate memory and thinking . . .”

[Emphasis added.]

And she points us to the work of Larkin and Simon (1987), Donald (1991), Norman (1993), Kirsch (1995), Stenning and Oberlander (1995), and Scaife and Rogers (1996) that all take a similar view of what drawings and other kinds of external representations are for and why. Essentially the same basic presumption, that designers engage in sketching in the face of cognitive limitations, is maintained in the work of Goldschmidt (1991, 1992, 1994a, 1994b), which has been used by many other researchers in the field. Arnheim (1995), commenting (admiringly) on Goldschmidt's work, explains that

“...A sketch is a reflection of the guiding mental image; but it is not and cannot be, identical with it [the mental image], and this difference is precisely what makes it [the sketch] a precious instrument for the designer.... By making a sketch, the designer supplies the mental image with the assistance of the optical image, which has all the properties of such visual percepts.”

The presumption that designers resort to sketching because they suffer from cognitive limitations was investigated by Anderson and Helstrup (1993) (see also (Anderson and Helstrup, 1993)). Their hypothesis was that designers decide to sketch when their creative processing runs out of cognitive resources, such as short term memory. They failed, however, to find evidence in support of this hypothesis. This negative (or at least non-positive) result did not, however, deter others to continue trying to investigate sketching in this way. Verstijnen et. al. (1998), for example, decided that if the problem is not with the limitations of short term memory, as Anderson and Helstrup hypothesised, then perhaps sketching occurs because of limitations of mental imagery. They took the view that the (mental) operations that lead to discovery are operations on mental images, and that sketching is needed if these operations cannot be done by the mental imaging system alone, or if the operations are easier to do on an external image.

The idea that people face cognitive limitations is not, of course, a view developed by design research. It forms the foundation of the so called Information Processing approach to cognition proposed and and actively pursued by Newell and Simon, see (Newell and Simon, 1972; Simon, 1981) and (Erricson and Simon, 1984).
In developing their information processing model of human problem solving, Newell and Simon, were influenced by Miller’s reporting, in 1956, that the capacity of short term memory is limited to seven plus or minus two different pieces of information, in contrast to the apparently much larger capacity of long term memory. The reason that Miller’s seven plus or minus two limitations is important in Newell and Simon’s model, is that their model defines problem solving as a set of cognitive processes which occur in short term memory.

What this and other Classical views of human problem solving ignore (or are ignorant of) is the essentially situated nature and working of memory. People always use external memory—memory in the world, or the world as memory—in preference to short term memory. Short term memory is used in situations where external memory breaks down in some way, or when it is not accessible for some reason. Our short term memory is for emergency use only, which is why it is not (evolutionary speaking) more developed and of greater capacity than it is. It doesn’t need to be. Miller’s seven plus or minus two is not a cognitive limitation, as he presented it, and as many others after him have taken it has. It is what is sufficient for survival.

However, given the influence of Newell and Simon’s information processing approach in both Artificial Intelligence research and Cognitive Psychology, it was a short step to conclude that designers too, and their designing, must suffer from the same cognitive limitations, and that they must do something to overcome these cognitive disabilities.

2. Thinking Happens in the Head

Newell and Simon, amongst others, are also responsible for developing and promoting the idea that thinking is something that happens inside the head, and only inside the head. Cognition is, according to this Classical view, a matter of mental and neuronal processes that occur in the brain. Perception is required to bring inside the head, via mental representations, problems posed to it by an agent’s environment. These are then worked on by various mental processes, and result in instructions to the agent’s motor systems to produce actions on the world, thus changing it in a way that resolves the problem, or, at least, partially resolves it. Newell (1981) offers one of the clearest of Newell and Simon’s various presentations of this view of an intelligent agent and how it works, and (Newell and Simon, 1976) presents the central conjecture upon which this view is based: problem solving as symbolic search.

Briefly, this view presents thinking as mental problem solving, in which a problem is represented in working memory and worked on by cognitive
processes drawn from long term memory, until a solution is devised. For Newell and Simon, and most other people working in the Cognitive Sciences, the mental representations constructed and and worked on by a problem solving agent are symbolic representations: combinations of syntactic elements which individually and collectively support unique interpretations.

Thinking then, is something that goes on in the head, and only in the head, supported by appropriate internal mental representations. Designing is taken to be a kind of thinking, as a kind of mental problem solving. In principle, all designing could thus take place inside the head of the designer, with no external signs of any designing happening until the final design is delivered. In practice, this is not what usually happens: designers make and use so called external representations, and in particular, they make and use sketches, especially in the so called early stages of any designing.

These external representations are thought of as external representations of internal mental images constructed during some designing. They are needed, as we have seen, to overcome the cognitive limitations of working memory or mental imagery. Furthermore, it is widely presumed that the sketches produced and use by designers, in the early stage of some designing, are precursors—on their way to becoming—the more detailed drawings that designers often use to express and present their final designs. These sketches start necessarily vague and imprecise because at the beginning of any designing it is not possible to specify everything about a final design, otherwise it would hardly be a design problem.

For example, Purcell and Gero (1998), in their comprehensive review of the sketching in design research, start out by saying:

“In the early conceptual stage of the design process, it is typical for an engineer or architect, for example, to use various relatively unstructured forms of pictorial representations such as sketches. As the design develops, other more structured forms of pictorial representations, such as plans or sections, become a part of the process.’’

What is not said here is that these “relatively unstructured forms of pictorial representations” first have to be made by the designer, before he or she can use them. They are the results of an externalisation of the mental images that the designer generates in the ongoing designing. In other words, what these sketches represent are (internal) mental images worked on by the cognitive problem solving processes. They are made external to relieve working memory, and, as a result, make them perceivable by the visual system, which allows the designer to ‘see’ things
in their images that they cannot see in them in their internal mental image forms.

The idea is that designers resorted to making sketches, external representations of their mental images, to overcome their natural cognitive limitations, and discovered, that by doing so they could use their visual system not just to view the external display of their internal mental images, but to also see other things in these externalised images that can promote and support further design thinking. So, what started out as a ‘crutch’ for working memory turned out to also be a ‘wheelchair’ for mental imagery, able to take the design thinking where its purely mental processing can not.

Investigation of the nature and role of all this drawing and reinterpretation of design sketches has received particular attention from Goldschmidt (see Goldschmidt (1991, 1992, 1994a, 1994b)), Schön and Wiggins (1992), and Goel (1995), all of whom identify some kind of reflexive dialogue that takes place between the designer and his or she sketches as a result of their construction and reinterpretation, see (Purcell and Gero, 1998) for a review.

What is clear from this and other work on sketching in designing, however, is that all the thinking that goes on in designing using sketches, is presumed to occur inside the head of the designer. Some thinking results in a mental image of some possible design or kind of design. This is copied out into a sketch (externally represented), with more or less precision. The sketch is then viewed, allowing the designer to ‘see’ new or other things in it (reinterpretation). This produces new contents in working memory that further thinking connects with other information or knowledge from long term memory (more problem solving). As a result, the emphasis of almost all sketching in designing research is to try to understand this (internal) thinking, by trying to understand what kind of thinking sketching aids and supports.

3. Designing as Problem Solving

Newell and Simon not only influenced the setup and programme followed by many researchers in the Cognitive Science, with their information processing theory of human cognition, they also established the dominant view of what designing is in design research: a kind of problem solving, see (Simon, 1973) and (Simon, 1981).

Simon (1973) compares ill-structured problems (ISPs)—problems whose structure lacks definition in some respect—with well structured problems (WSPs); problems that can be solved by search using a General Problem Solver (GPS) type of system. Simon starts by identifying five properties of
well structured problems that make them solvable using a GPS type system. He then takes designing a house as a (clear) example of an ill-structured problem, and proceeds to show how an architect designs a house by solving a series of well structured problems. In summary, Simon, says that

“The design process . . . can be composed from a combination of a GPS, which at any given moment finds itself working on some well structured subproblem, with a retrieval system, which continually modifies the problem space [that the GPS is working on] by evoking from long term-memory new constraints, new subgoals, and new generators for design alternatives. We can also view this retrieval system as a recognition system that attends to features in the current problem space and in external memory (e.g., models and drawings), and, recognizing features as familiar, evokes relevant information from memory which adds to the problem space (or substitutes for other information currently in the problem space).”

A little later, he adds that

“. . . All of the necessary definitory [sic] information is potentially available, but distributed through long-term memory. It is retrieved through two mechanisms: first, the normal subroutine structure, which enables processes to call subprocesses and to pass input and output information from one to another [i.e., problem decomposition]; second, the evoking mechanism, which recognizes when certain information has become relevant, and proceeds to retrieve that information from long-term memory.”

Sketching, in designing, is thus used to help this second evoking mechanism, to bring out of long term memory relevant information that can be used to restructure the current problem space, or to introduce new problem space operators, for example.

We can see this idea expressed very clearly by Goldschmidt (1991), when she argues that sketching provides a particularly effective procedure for retrieving, from long term memory, relevant conceptual knowledge and knowledge of previously analysed designs and examples. The sketch is used to externally represent some aspect or part of the current state of the problem space of the internally functioning GPS, so that visual perception can be used to better access relevant knowledge or experiences held in long term memory. See (Goldschmidt, 1997), for a further working out and development of this idea.

Designing is thus taken to be, as Simon proposed, a combination of a GPS-like system, able to solve well-formed problem, combined with a retrieval process that finds, from long term memory, information that is
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used to restructure the well formed problem being worked on, until it is one that yields a final solution. And sketching is widely understood to be the tool used to do the evoking needed to drive the retrieval process, by making explicit, and thus visible, parts or aspects of the current problem space.

4. Designing as Exploration

In an attempt to respond to what are claimed to be important inadequacies in Simon’s theory of designing as problem solving, Smithers has proposed Designing as Exploration, as an alternative, see (Smithers and Troxell, 1990; Smithers, 1992; Smithers, 1998; Smithers, 2000).

Designing as Exploration (DasE) differs from Designing as Problem Solving (DasPS) in two important respects. First, DasE does not presume that designing starts with a problem at all, ill-structured or ill-defined. It proposes that synthesising a problem, whose solution can satisfy the motivating needs or desires, is a central and necessary aspect of real designing. Second, it does not presume that ill-structured (design) problems are solved by decomposition into well defined subproblems, as in DasPS. DasE proposes that a final well formed problem definition is constructed incrementally, together with the construction of a solution to it, as designing proceeds, via a symbiotic process of exploring what problems and their solutions might form a basis for understanding and satisfying the needs or desires that motivated the designing.

Designing as Exploration was developed in an attempt to better reflect what designers and design researchers have to say about the nature of designing. In particular, it is an attempt to capture and give an explanation for what Lawson (1990) called “One of the essential characteristics of design problems,” which is that “they are often not apparent but must be found.” As Lawson latter explains

“It is clear from . . . the nature of design problems that the designer must inevitably expend considerable energy identifying the problems confronting him [sic]. It is central to modern thinking about design that problems and solutions are seen as emerging together rather than one following logically upon the other. . . . That is, both problem and solution become clearer as the process goes on.

Thus, although DasE includes the solving of well formed problems, it characterises designing as an incremental constructive process. One in which the designer must actively explore how some client’s need or desire might be understood and eventually fully expressed as a well formed
problem, which has a solution that can be shown can act as a specification for a design that will satisfy the client’s needs or desires.

For designing as exploration to work, it must be understood as a situated activity; situated in the context and conditions of the designer or designers involved, and in the context and conditions of the client, which includes current socio-economic currents, conditions, fashions, and expectations.

From the point of view of DasE, sketching is to be understood as part of the process of exploring what kind of problem might deliver a solution that could form the basis for a final design. The dialectic that sketching supports is not between externalised images of possible solutions to a given design problem and the contents of long-term memory needed to solve it, but between possible problems and their solutions. Given their nature, sketches can be seen either as expressing aspects or characteristics of possible problem formulations, or as expressing aspects or characteristics of solutions to these possible problems. They support multiple readings. They can either be seen as outlines of kinds of problems, or they can be seen as the forms of possible solutions to these problems. Sketching is thus a kind of reasoning that is essential and necessary in the incremental and symbiotic development of a final well formed problem definition and a solution to it that can act as a final design.

The early sketches common in many kinds of designing, are not early depictions of possible designs, they are constructions used to identify possible problem formulations and their possible solutions. Constructions that can be actively manipulated, modified, and worked on, in a process of identifying alternative problem formulations and solutions.

The dialog that sketches and their construction and manipulation support is between kinds of possible problems and possible solutions to them. It is a dialog that must go on in designing in order to arrive at both a proper way of understanding the needs and desires that motivate the designing, and a design that can satisfy these needs and desires. It is a dialog that the designer both realises and observes, and, in so doing influences its content and direction using knowledge of the design situation and context, together with knowledge of the domain, other designs and his or her experience.

5. Sketching as Thinking

From the point of view of Designing as Exploration, early design sketches are not well described as representations of internal mental images of possible solutions that are reinterpreted after visualisation. Early sketches form a kind of scaffolding for the on going designing, a scaffolding that acts to support the designing, by supporting an effective exploration of the
possible problems and their solutions in a way that is well connected to the designer and client conditions and the contexts that must bear on the designing.

In this sense, early design sketches are not representational devices, used to aid memory or mental imagery, they are the elements of a language of thought needed in designing. A language that is used to ‘talk about’ and relate important aspects the external situation of the designing to internal mental processes. Sketching is thus better understood as a way of thinking needed in designing to properly connect the otherwise free ranging internal thinking of a designer to the important realities of the actual design situation. It is a way of thinking that is in better contact with the real world being designed for, and in better contact with the designer’s understanding, knowledge, and experiences of the real world. It is a way of thinking like talking out loud can be a way of thinking, or like jazz improvisation can be a way of thinking. It is a kind of thinking that cannot be done in any other way.

McMullan (1990) expresses these ideas better when he says

“Drawing is a physical act which puts us in touch with how we really experience space and form. Design, when you examine its fundamental impulse, is informed reflex. We make shapes, chose intervals, and decide on hierarchies all from deep instincts, which are expresses in the act of drawing. The drawing hand, moving at the will of our purposeful choices and also the subconscious biases in our nervous system, creates the basic structure upon which all other aesthetic decisions are made.” . . . Without drawing there would be no way to meld the world of the rational and the world of the intuitive.” . . . In drawing, the physical act itself provides an intensifying “container” which makes possible a kind of thinking which occurs at no other time. Typically, we advance the drawing half from reason and half from intuition, and the drawing itself provokes still more intuitive and associative responses which in turn provoke more drawing. This fertile interaction between the hand making the marks and the mind responding occurs most successfully with artists who draw well . . .”

This might seem, at first, to be saying the same as Goldschmidt, when she talks of her moves and arguments, (Goldschmidt, 1991), but the drawings that McMullen speaks of are not the result of attempts to externally express pre-formed internal mental images, so that they can be made accessible to the visual perception system. McMullen is talking about drawings, sketches, that come about by a direct processes of acting to make marks on the paper, and letting the thoughts these marks provoke influence the making of further marks. A well practice skill at drawing is,
according to McMullen, the way a designer relates his or her designing to the real world he or she is designing for. Drawing or sketching in designing is thus a necessary kind of thinking in designing. It is not a device for aiding memory or mental imagery.

One of Goldshmidt’s subjects expresses this idea that sketching is a way of thinking when she says

“. . . I can’t get very far with just [mentally] thinking about it without drawing something . . . So, sometimes I just get a lot of lines out and then start seeing things in it.” (Goldschmidt, 1991, page 129)

All these lines that this subject just gets out, are not an external representation of an internal mental image, which she then reinterprets. They are the starting marks of some sketching thinking.

Tversky (1999), despite proclaiming the idea that sketches are a kind of tool used to facilitate memory and thinking (see section 1), identifies an important reason why sketching or drawing works so well as a kind of thinking in designing, in the way McMullan describes, when she says

“. . . Although drawings can be like images, they frequently contradict many of the properties attributed to images. To put it succinctly, drawings reveal people’s conceptions of things, not their perceptions of things.”

A designer must express his or her conception of things in order to explore ways that a client’s needs or desires might be understood and set up as a problem which has a solution that will satisfy the client’s needs or desires. Sketching or drawing is the way designers do this important and necessary kind of thinking in designing.

Goldschmidt (1999) comes very close to admitting this, when, writing of the history of sketching in art and designing, she tells us that

“The desire to experiment, to revise and look for alternatives which the activity of freehand rapid sketching supported, was of course in perfect harmony with the innovative spirit of the renaissance. Therefore, the assimilation of sketching into artistic and design practices was quick to occur. Most appropriately, the incomplete, partial, rapidly hand drawn images on paper that we refer to as study sketches, were called “pensieri” (Olszweski, 1981), meaning ‘thoughts’ in contemporary Italian. Sketches were then, and still are today, an aid to thinking and, we maintain, under certain circumstances their making is thinking itself.”
Goldschmidt’s seeming hesitation at calling sketching a kind of thinking here, could be removed by dropping the Classical ‘thinking is only in the head’ stance she adopts, and describing the “freehand rapid sketching” not as supporting the experimentation and revision, but as being this experimentation and revision. The sketching is not an external version of some experimentation and revision going on in the head of the designer. It is the experimentation and revision. The renaissance Italian’s were right. This kind of rapid freehand sketching are thoughts. This kind of sketching is a kind of thinking, not some outward sign of it going on in the head.

Suwa et. al. (2000), in a protocol study to investigate how designers go about dealing with the fact that designing does not start with a problem statement, not even an ill-structured or ill-defined problem, identify what they call S-inventions as an important aspect of designing that identify design issues, requirements, and goals, as designing proceeds. They refer to S-inventions as “unexpected discoveries,” as if a more competent or more able designer might be expected to identify them at the start of designing, but these S-inventions are not so much unexpected discoveries, as the kinds of discoveries to be expected in designing. In terms of Designing as Exploration, S-inventions are a basic aspect of the incremental exploration of what kind of problem could provide a suitable way of understanding the motivating needs and desires, such that a solution to this problem will result in a design that satisfies the needs and desires.

In their conclusions, Suwa et al., claim that their work offers empirical evidence for what they called two anecdotal views of designing. First, that “. . . the problem-space and the solution-space of a design problem evolve together as the process goes on, and secondly, [that] designing is a situated act.” A conclusion strongly supportive of Designing as Exploration. Their work also shows that early sketching plays an important role in S-invention, which also supports the idea that sketching is a kind of thinking needed for doing designing.

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