SKETCHING, ANALOGIES, AND CREATIVITY

On the shared research interests of psychologists and designers

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Abstract. Paper and pencil sketching, visual analogies, and creativity are intuitively interconnected in design. This paper reports on previous and current research activities of a psychologist (the 1st author) and an architect/designer (the 2nd author) on issues concerning sketching and analogies, and analogies and creativity respectively. In this paper we tried to unite these findings into a combined theory on how sketching, analogies, and creativity interrelate. An appealing theory emerges. It is hypothesized that with no paper available or no expertise to use it, analogies can be used to support the creative process instead of sketches. This theory, however, is a tentative one that needs more research to be confirmed.

1. Sketching

Within creative professions, mental imagery often interacts with paper and pencil sketching. Artists and designers (among others) frequently engage into sketching and, without any proper paper available, will often report frustration and resort to newspaper margins, back of envelopes, beer mats or the like. Although anecdotally, this frustration seems to be quite common, and demonstrates the importance of paper and pencil sketching as a necessary aid to mental imagery. Paper and pencil sketches are one form of externalization of mental images, and therefore can inform us about characteristics of these images. These characteristics are of particular interest to psychologists in order to develop theories about mental imagery, its products and processes, and to compare it with visual perception. Nowadays, mental imagery is hotly debated in psychology and most psychologists believe that the exact nature of mental images is in any case still open to discussion. This, although in 1994 the ‘Imagery Debate’
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(see for example Reisberg (1997) in reaction to Rouw and Kosslyn, (1997)) was claimed to be resolved (Kosslyn, 1994).

Experienced sketchers, like designers, can be expected to produce the most faithful reflections of mental images in their sketches. They are therefore ideal subjects for studies by psychologists. The investigation of sketching-behavior as a means to gain insight in mental imagery is taken up by only a small number of psychologists and usually they study novice sketchers (e.g. Anderson and Helstrup, 1993ab), although there are some recent exceptions (Verstijnen, van Leeuwen, Goldschmidt, Hamel, and Hennessey, 1998; Verstijnen, van Leeuwen, Hamel and Hennessey, 2000).

Sketching is usually seen as a form of ‘Enacted Imagery’ (Reisberg and Logie, 1993), a term which does not only cover the close bond between sketching and imagery, but also suggests that sketching fulfills a need that arises from imagery. One may wonder what need experienced sketchers might encounter, capable as they are to produce the most faithful reflections of mental images. However, if the act of sketching does not fulfill a basic need, for reasons of economy it probably would not be performed at all, at least not that often and with such eagerness.

In order to gain insight in mental imagery and sketching, a distinction should be made between mental images (or mental products) and mental processes in imagery. Mental images can be created by ‘loading’ information from memory on what has been called the ‘visuo-spatial sketchpath’ (or scratchpath, Baddeley, 1986), one of the slave systems of working memory. Once on this sketchpath, blocks of information can be combined in various ways. Combining is one of the processes in mental imagery that enroll without apparent difficulty (Verstijnen et al., 1998).

Finke and Slayton (1988) showed, for example, that it is easy to combine in mental imagery a capital letter D and a capital J into an umbrella. Probably, because of this ease of enrolling in mental imagery, combining is a mental process that is not supported by sketching. Experiments in which subjects were allowed to sketch during a combining task did not reveal any surplus for sketching (Verstijnen et al., 1998; Anderson and Helstrup, 1993ab).

While the process of combining enrolls quite easily before the mental eye, another process called restructuring (or reconstruals) causes considerable difficulty (e.g. Reisberg, 1987; Verstijnen et al., 2000). Restructuring involves a structural change in the information that is loaded from memory. This can be illustrated with the example in Figure 1.

![Figure 1](image-url)

*Figure 1.* When two isosceles triangles (displayed on the left) are combined, the figure on the right results (adapted from Chambers and Reisberg, 1992).
When two isosceles triangles (Figure 1 on the left) are retrieved from memory and combined (Figure 1 on the right) before the inner eye, the resulting figure consists of two overlapping triangles. However, the interpretation of the rightmost figure in Figure 1 as consisting of two overlapping triangles, is but one of the possible interpretations of this figure. Closer perceptual inspection shows that this figure can also be conceived as consisting of two hourglasses, or even two overlapping chevrons. Visual imagery, in contrast, will in general stick to its original structural interpretation of two isosceles triangles.

Although the issue of restructuring is one of the hottest topics that is pondered upon in the Imagery Debate, with many experiments refuting the zero-level performance of mental imagery as was found by Chambers and Reisberg (e.g. Hyman, 1993), it is clear that the difficulty met with restructuring, sharply contrasts with the ease of combining.

1.1 SKETCHING AND RESTRUCTURING

Because of the difficulty that the process of restructuring meets before the inner eye, this process is likely candidate for paper and pencil support. Just as easy it is to restructure the rightmost figure in Figure 1 visually, sketchers may inspect their sketches visually and discover alternative interpretations.

In a number of experiments, the hypothesis stating that paper and pencil sketching aids restructuring, proved to be fruitful. In one experiment for example (Verstijnen et al., 2000), figures like those in Figure 1 on the right were shown to the subjects (experienced sketchers). It was asserted that the subjects stored just one particular interpretation in memory, say a two-triangle interpretation. Subsequently, the figure was removed and subjects were asked to indicate whether (say) a chevron made part of the figure. Subjects, who were not allowed to sketch, turned out to act at chance-level, indicating that they just guessed about the presence of the chevron. Subjects, however, who were given paper and pencil, in general started to sketch spontaneously and discovered the chevron quite easily.

This result, however, could not be replicated with inexperienced sketchers. Novices turned to sketching as often as the more experienced sketchers, but failed far more often to detect the figures that required restructuring.

2. Sketching and Creativity

The above experiment involved a task known to require restructuring and also known for the difficulty it confronts mental imagery with. However,
also in a task known to test combining (Finke’s figural combination paradigm; e.g. Finke, 1990), restructuring turns out to take place. In an experiment (Verstijnen, 1998), experienced sketchers were shown three simple 3D shapes with which they had to create an object, just like the umbrella in the above example. Half of the subjects were allowed to sketch, the other half had to perform the task in mental imagery. It turned out that combining was as easy for the mental imagery group as it was for the sketch group, but that the latter group had altered the original structures far more often. A cone, for example, could show up in sketches as a tube, or a sphere was turned into a half-sphere, see Figure 2.

As was the case in the original Finke studies, also in this study the resulting objects were rated on creativity. Combining and restructuring both related to this measure of creativity, suggesting that both mental processes are needed in order to conceive creative products. Since the process of restructuring depends strongly on sketching, the results of the experiments suggest that sketching constitutes a crucial part of the creative process.

The finding that sketching improved restructuring could, however, only be established with experienced sketchers. With novices no such result was found.

3. Sketching and Analogies

In both the above-cited experiments, inexperienced sketchers fell short in using sketching as a means to restructure. This, in combination with the finding that restructuring and creativity may be related, may suggest a sad prospect for these people. The inability to use sketching as a form of
externalizing may restrict them to things they already knew and stored in memory.

Although anecdotal, the story of the scientist Kekulé may suggest a way out for the ‘sketchically’ handicapped. As a chemist, Kekulé knew all the rules for the make-up of chemical structures. At his time, one of these rules prescribed that molecules were all string-like structures. This rule, in combination with what he knew about the elements making up the benzene molecule, posed him for an unsolvable problem. He probably combined and recombined all the known facts before his mental eye, without reaching a solution. Were it not for his fireplace, it is claimed that he may never have solved the problem. In the flames in his fireplace he saw snakes (string-like structures) biting each other’s tails, thus forming a ring-structure. Analogous to the tail-biting snakes Kekulé bent his string-like chemical structures and thus discovered the well-known benzene ring.

Apart from Kekulé’s story, many other anecdotal stories are known, were scenes in the environment provided crucial visual clues for problem-solving through restructuring. Think for example of Archimede and his raising bath water. His ‘Eureka!’ (‘I have found it!’) still echoes.

Throughout the history of architecture, many architects reported to have used analogies, not infrequently with splendid and highly creative results. Interestingly, however, a considerable part of today’s architects and design teachers believes the use of analogies, and a fortiori of within domain ones, to increase the danger of students blindly copying existing projects (Heylighen, 2000), a phenomenon known as design fixation (Christiaans and van Andel, 1993; Purcell and Gero, 1996).

However, these stories about Kekulé and others, are all anecdotal. Some authors even claim that these stories are in fact apocryphal, made up to embellish the findings. For example, according to Noe and Bader (1993) Kekulé must have read Lofschmidt’s book that appeared several years earlier, in which Lofschmidt proposed a circular structure.

According to some psychologists (e.g. Hadamard, 1945), psychologists will never be able to study these processes in their laboratories, because the process of incubation is that rare and unique. Others even claim that incubation is a non-existent process (Weisberg and Alba, 1981). Indeed, experiments that have studied the influence of visual displays on problem-solving did not find any additional value. Gick and Holyoak (1983), for example, studied the influence of visual displays on the solutions in a classical problem-solving paradigm. In this paradigm (Duncker, 1945), subjects were given a number of seemingly unrelated stories consisting of a problem and its solution, before they had to solve a problem on their own (the target). Although one of the preceding stories (the source or base) was structurally analogous to the problem at hand, most subjects failed to detect the connection, and henceforth failed to solve the problem at all.
In the original version of the paradigm, the preceding stories were offered verbally to the subject. Gick and Holyoak’s additional visual displays, showing the abstract structures behind the problem and its solution, did not improve on subjects’ problem-solving performances. Nor was such an effect found by Verstijnen, Wagemans, Heylighen, and Neuckermans (1999) (see also Verstijnen and Wagemans, in preparation).

We, however, hypothesized that restructuring is needed in order to solve the problem in Duncker’s paradigm. In Duncker’s paradigm, subjects have to solve the so-called Radiation Problem. In order to solve this problem, subjects have to get rid of the very idea that a laser beam is just a single compact beam coming from one direction only, and to restructure this into several small beams coming from different directions. Focusing these small beams from several directions onto a tumor-site and hence concentrating their actions, constituted the solution for the radiation problem. One of the preceding stories (the source problem) also consisted of dispersing a unity into several small elements and converging these elements onto a goal-site. This preceding story was a story about a general splitting up his army in order to attack a castle from different directions at the same time.

We (Verstijnen et al., 1999; Verstijnen and Wagemans, in preparation) hypothesized that if restructuring is involved in this paradigm, sketching may play an advantageous role in solving the problem. In a 2x2 design we varied presence vs. absence of visual displays presented next to every preceding cover story, and whether or not subjects were allowed to sketch during problem-solving (sketch vs. no-sketch condition). Both the sketch and the no-sketch condition had to write down a complete verbal description of their final solution before drawing it; a procedure applied by Finke and Slayton (1988) to minimize sketching in the no-sketch conditions. Each subject had to solve two problems: Duncker’s original radiation problem, and a specific architectural problem. Afterwards subjects were asked to fill in a questionnaire.

The hypothesized effect of sketching for experienced sketchers (3rd year student architects, n=48), showed-up\(^1\). Furthermore, new data with novices (3rd year psychology students, n=60) as subjects show only a small and insignificant increase for this group.

It turned out that, although sketching increased solution finding for experienced sketchers (architects in the sketch-group), these subjects generally indicated not to have based their solution on the analogy. From those who solved the radiation problem, only 41.67% indicated to have

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\(^1\) An ANOVA with VisualDisplay and Sketch as independent variables shows a significant effect for Sketch; F(1,44)= 4.99; p=.031 for the supermarket problem, but an insignificant effect for the radiation problem; F(1,44)= 1.40, n.s. We (Verstijnen et al., 1999) attributed this difference to domain-expertise. The variable VisualDisplay did not contribute.
used the analogy, the rest of the sketch-group solvers said not to have used it. For the solvers of the architectural problem, this partitioning is even more of the hook. Only 18.75% of the solvers detected the analogy, whereas the rest claimed to have solved the problem without noticing the analogy. These results are in sharp contrast with those obtained in the groups that were not allowed to sketch, as they merely indicated to have noticed the analogy with the preceding story.

A different story applies to the novices in the above experiment. Whether or not they were allowed to sketch, most of the solvers of the problems indicated to have noted the analogy with the preceding story. The results of these latter groups are in agreement with the results reported by Gick and Holyoak (1980), who reported that in the absence of a prior analogy only 10% of the subjects produced a solution.

These results for experienced sketchers were replicated in a second experiment. In this experiment the experimental procedures were exactly the same as in the previous experiment, only this time subjects had to illustrate the preceding cover stories before reading the target problems. Illustrating the cover story can be expected to strengthen the memory trace. According to some (e.g. Anderson, 1993) analogical transfer becomes more likely when the memory trace is strengthened. But even with this set-up the experienced sketchers more often failed to detect the analogy than the non-sketchers. This even though in some cases the self-made display almost perfectly matched the drawing subjects provided with the solution, questioning the idea that retrieval of analogies is based on the summation of activation resulting from multiple shared features (Holyoak and Koh, 1987).

If we take the self-reports of the subjects at face value, then the conclusion that can be drawn from the above experiments, is that for experienced sketchers sketching may come as an alternative to finding analogies; novices, instead, will have to rely on the luck of having an analogous structure passing by, combined with the luck of noticing the analogy.

But as Kekulé’s case shows, taking self-reports at face value might not be wise, and therefore new research is undertaken to gain insight in the processes underlying the solution path.

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2 For experienced sketchers (architects) this contrast between sketch-group and no-sketch group showed to be statistically significant: $\chi^2 = 8.85; p = .0029$.

3 The contrast between novices and experienced sketchers as to whether analogies were said to be used to reach the solution, shows up in a statistically significant interaction between the variables Expertise and Sketch F(1,37) = 8.79; p = .005 and F(1,37) = 3.99; p = .052 for the architectural problem and radiation problem respectively. Once again the factor VisualDisplay did not contribute.
If, however, analogies can play a similar role as sketching in solving problems, then it would be interesting to find out whether the positive relationship between sketching and creativity (as outlined in section 1.2) also applies to analogies and creativity. Many authors (e.g. Holyoak and Thagard, 1996; Keane, 1988) acknowledge that this relationship must exist. This, however, is not directly investigated in the above experiments, but the line of research reported below may provide insights in this issue.

4. Analogies and creativity

A more precise control over the use of analogies than self-reports only, was applied in experiments after the relationship between analogies and creativity (Heylighen, 2000; Heylighen and Verstijnen, submitted). In a first experiment, a group of 2nd year architecture students was asked to design an entrance hall for an apartment building. Half of them had access to within domain sources – high quality entrance hall projects of previous years – the other half did not. In order to investigate the effects of this (lack of) access, the final projects of all students were judged both by the design teachers who had supervised the students, and by two external design teachers. Apart from a global score reflecting the overall quality of the project, the judges had to rate each project on several five-point scales, one of which measured the creative character of the design. Analysis of the judges’ scores revealed that exposure to within domain sources has the potential to improve on creativity.

A second experiment further investigated the effects of analogies in architecture (Heylighen, 2000; Heylighen and Verstijnen, submitted). In this experiment, 4th year architecture students could choose one out of two reuse projects: either the conversion of a former fabric hall into a public library, or a reorganization and extension of their school, which is located in a 16th century castle. All students had access to a collection of relevant sources – examples of high-quality reuse projects – be it this time in the form of an on-line digital case library. The number of times each student logged on to the system was counted. Like in the previous experiment, the end-products were rated by a number of judges on five-point scales. Given the results of the first experiment, we hypothesized that an increase in use of this case library would have a positive effect on students’ design results. Interestingly, however, this hypothesis was only confirmed for the students who had chosen the public library. For these subjects, using the case library
positively affected the overall quality as well as some specific aspects of their design, including its creative character. For the students who had chosen the architecture school, only one aspect of their design – the project’s attitude towards the existing building – was affected by using the tool, be it in a negative way.

The most plausible explanation for this contrast between both groups seems to lie in the selection of sources. The case library contained eight libraries compared to only one school building. Moreover, of the twenty-one reuse projects, nine were situated in a factory hall or other industrial building and thus particularly relevant for the library design, whereas no more than two dealt with a castle-like building, being more relevant for the school design.

An ad hoc explanation of our data based on distance between base and target would confirm studies in psychology, which demonstrate that most novices only benefit from using examples that are identical in format (Mayer, 1992). A plausible rationale for this phenomenon is given by Gentner’s structure-mapping theory: if students have difficulty in mapping the source (the example) onto the target (the design task at hand), they will not be able to use the example effectively to solve the target problem (Gentner, 1983). For novices, examples are thus most powerful when they map directly and obviously onto the target problem.

An explanation based on distance between source and target, however, requires more in-depth experiments. Currently we are investigating whether a measure of distance can be related to the frequency of analogy use.

5. Sketching, Analogies and Creativity

In the previous sections links between sketching and creativity (section 2), sketching and analogies (section 3), and analogies and creativity (section 4) are described. At this point, it would be tempting to conclude that sketching, analogies, and creativity are interconnected as well, and that with no paper available or no expertise to use it, analogies can be used to support the creative process. However, in order to connect all the above findings, they need at least be comparable and on a similar level of explanation. Yet the differences between the experiments are too large to connect the reported findings in a straightforward way.

What figures most prominently as a difference between these experiments is the issue of open-ended versus closed problems. In the

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4 In a regression analysis with frequency of use and a score on a general design course as independent variables and judges’ global score of the end-product as dependent variable, frequency of use shows up as a significant contributor; t(14)=3.13; p=.007.

5 Idem, but now with creativity score as dependent variable; t(14)=2.43; p=.029.
experiments reported in sections 2 and 3 subjects had to solve a problem with only one good answer, the subjects in the 4th section had to solve an open-ended problem. Open-ended problems have several solutions, and consequently several analogies can be used to solve the problem.

The issue of between and within domain analogies should also be taken into account. Vosniadou and Ortony (1989), tell apart between-domain analogies where source and target belong to different remote domains, and within-domain analogies where source and target stem from the same domain. This may clarify why the Duncker experiments analogies revealed no surplus for visual-displays whereas the experiments outlined in the previous section do. The experiment with the digital case library showed that only within-domain analogies improved on subjects’ performance; between-domain analogies did not. In the experiments with the Duncker paradigm, the analogies can be considered as being between domain (a general’s considerations about how to conquer a castle is generally not an issue that bothers physicians and vice versa). Therefore, the between domain character of the visual displays may have prevented subjects to detect the analogy in the experiments with the Duncker paradigm.

Yet another difference can be found in the nature of the visual displays. In the Duncker experiments no more than the underlying structure was displayed in a reduced and static way, in contrast the visual displays available during the student assignment were rich and dynamic. The latter displays could be explored in several ways. Beveridge and Parkins (1987) have showed that exploration and dynamic representation can also be helpful within Duncker’s paradigm. In their experiment’s subjects were handed several transparencies with rays. The subjects had to pile these transparencies. The intensity at the point of overlap of several rays illustrates the summation principle behind the radiation problem. With this set-up Beveridge and Parkins found an increase in analogical transfer.

Apart from the differences given, several other differences between the experiments exist. In this respect, it is clear that the findings of the reported experiments do not allow to be connected straightforwardly. However, the tentative conclusion that with no paper available or no expertise to use it, analogies can be used to support the creative process, is appealing and seems intuitively plausible. No need to say that we will go on investigating; the shared interests of designers and psychologists probably will bring about many more clarifying experiments on the issue.
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References


