Sketches of Creative Discovery
A Psychological Inquiry into the Role of Imagery and Sketching in Creative Discovery
CIP-GEVEVENS KONINKLIJE BIBLIOTHEEK, DEN HAAG

Verstijnen, Ilse

Sketches of Creative Discovery.
A Psychological Inquiry into the role of Sketching in Creative Discovery
Thesis Technische Universiteit Delft
- With ref. - With summary in Dutch.

ISBN 90-9010442-9

Subject headings: Psychology, Imagery, Perception, Creativity, Sketching

Cover: © S. Dali, 1997 c/o Beeldrecht Amstelveen, Demart Pro Arte
Cover design: Corrie v.d. Lelie, Ralph Stuyver

All rights reserved. No part of this book may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording or by any information storage and retrieval system without permission from the author.
Sketches of Creative Discovery
A Psychological Inquiry into the Role of Imagery and Sketching in Creative Discovery

PROEFSCHRIFT

ter verkrijging van de graad van doctor
aan de Technische Universiteit Delft,
op gezag van Rector Magnificus Prof. dr. ir. J. Blaauwendraad,
in het openbaar te verdedigen ten overstaan van een commissie,
door het College van Dekanen aangewezen,
op dinsdag 22 april 1997 te 10.30 uur

door

Ilse Marieke VERSTIJNEN

docteranda in de psychologie

geboren te Hengelo (O.)
Dit proefschrift is goedgekeurd door de promotor:
Prof. J.M. Hennessey

Toegevoegd promotor:
Dr. C. van Leeuwen

Samenstelling promotiecommissie:
Rector Magnificus, voorzitter
Prof. J.M. Hennessey, TU Delft, promotor
Dr. C. van Leeuwen, UvA Amsterdam, toegevoegd promotor
Prof. dr. ir. R. M. Oxman, Technion Haifa, Israël
Prof. dr. J.M. Dirksen, TU Delft
Prof. G. Goldschmidt, Technion Haifa, Israël
Prof. S.A.R. Scrivener, University of Derby, Engeland
Dr. R. Hamel, UvA Amsterdam
‘Tis all in pieces, all coherence gone:
All just supply and all relation.’

John Donne
Paper-and-pencil sketching is used in several stages of the design process. Designers generally distinguish between idea-sketches and presentation sketches. Idea-sketches are made in the early phases of design. They function as a tool to interact with imagery (Goldschmidt, 1991; 1992a) and are predominantly for private use (Herbert, 1988). Presentation-sketches are made in later phases (Garner, 1990). They are generally made when the object of design has reached its more definitive state and are used to present the result of the design to others. Because of their early appearance in the design process, idea-sketching will have a more important role in creative processes than presentation sketching.

Making presentations for the purpose of showing these to others is relatively well-supported by existing computer-tools such as CAD. The making of idea-sketches may require different facilities. Computer support for early sketches, however, is much less developed (Hennessey, 1992). A problem is that the nature of these sketches is less well understood than that of presentation sketches.
The IDEATE-project (Hennessey, 1992; Kolli & Hennessey, 1993; Stuyver & Hennessey, 1995) is one of the projects which acknowledges the beneficial aspects of computer tools for supporting idea-sketches. This project envisages the development of a tool, the IDEATOR. The IDEATOR will contain all facilities that are needed for storing sketches in memory, copying and pasting, displaying imported pictures or video's on the sketch surface. But in addition, the IDEATOR may have to include a set of additional facilities, based on insight in the drive or motivation behind idea-sketches.

In order to include such facilities, the drive or motivation behind idea-sketches has to be studied more closely (Fish & Scrivener; 1990; Versstijen, Stuyver; Hennessey, van Leeuwen, & Hamel, 1996). The unpredictability of idea-sketching behavior is a challenge to such study. The private nature of these sketches, their proverbial appearance on the back of an envelope, the absorption of the sketcher in his or her activities, makes idea-sketching a fascinating topic, which has been an impetus, both for self-reflexive activities of expert sketchers such as designers themselves, and for experimental studies by psychologists.

Until now, paper and pencil sketching has been discussed predominantly among those who are themselves actively engaged in sketching, such as industrial designers and architects. Their descriptions range from on the hand self-reports (e.g. Garner, 1990), to objective descriptions of the sketch process (e.g. Goldschmidt, 1990; 1992b; Schenk, 1991) on the other. This literature concentrates on the sketching activities themselves; the mental processes, from which the sketching behavior originates are still to be investigated. Psychologists have only recently touched upon this issue (Versstijen & van Leeuwen, 1995).

Anderson and Helstrup (1993ab, 1995) were the first within the information processing framework of psychology to systematically explore the field of idea sketching. Their seminal proposal was, that the decision to sketch is made when creative processing is met with resource limitations. In their experiments, however, they failed to obtain support for this view. This still leaves unexplained why idea-sketching could be useful.

An alternative approach is taken in the present dissertation. The proposed approach draws heavily on an understanding of processing in mental imagery. Some imagery processes are easy to perform and others are hard, and sketching is used to compensate for the hard ones. This conclusion could be drawn as the result of two experimental studies, presented in this dissertation. This conclusion connects the phenomena of sketching to the field of mental imagery, creativity and discovery and may add some new insights to these domains.

The present dissertation is the result of my participation in the IDEATE-project. For this reason, the implications of this research for the design process are specified. This is done in two chapters: in the introduction and conclusion sections. These sections will be united in an article designated for industrial designer engineers. Two of the three chapters in-between contain experimental studies; the third is a case study of a creative process by an artist, the Dutch abstract painter Paul Kleijne. These three chapters are submitted for publication as separate articles to psychological journals.
CHAPTER

Introduction

One day, the story goes, Archimedes jumped out of bath and ran joyfully and nakedly through the streets of Syracuse. Finally, he had discovered the solution to a problem which had been bothering him. For a long time, he had wondered how to measure the girth of an irregular object. Obviously, the discovery came to him at a moment he had not anticipated. This aspect of discovery is more frequently encountered in anecdotal evidence and self-reports. Friedrich von Kekulé reports drowsing in front of his fireplace when, the solution to a problem he had been working on showed up. The image he saw in the flames about snakes biting their own tails hinted him to drop an assumption in organic chemistry, which prescribes that organic molecules must be strings of carbon atoms. This enabled him to come up with the idea of a ring structure for the benzene molecule.
Kekulé's discovery came to him in a state of reduced awareness, but this appears not to be the rule. Henri Poincaré was entering a bus which was to take him on a geological trip, when suddenly he glanced a fundamental property, uniting a hitherto unrelated group of mathematical functions. These, and several other reports of scientific discoveries can be found in, for example, Dreiastdt (1968), Miller (1986), and Rothenberg (1979). All the anecdotes have the unanticipated character of the discovery in common.

The unanticipated character of discovery makes it unlikely that these creative individuals had paper and pencil available to support the breakthrough in their thinking with sketching. In the light of this evidence, it may seem slightly audacious to suggest that sketching could have an important role in discovery. Yet, this is what will be concluded from our studies.

That externalization fulfills a need is suggested by the fact that most artists and designers use some kind of externalization, e.g. sketching and claying. They consider this essential for their creative process and will report frustration if hindered in doing so. Sometimes, people find their way around this frustration and this is why sketches can be found on backs of envelopes, edges of newspapers, or napkins.

Designers have called sketches made in such a situation idea-sketches. In contrast to presentation-sketches, idea-sketches are made in the early phases of design. They function as a tool to interact with imagery (Goldschmidt, 1992b) and are predominantly for private use. Because of their early appearance in the design process, idea-sketching will have an important role in creative processes.

The question, why artists and designers need externalization for discovery in a creative process can be approached in a variety of ways. The most direct way appears to be the introspective way. Many artists and designers have studied their own creative processes and have launched a great variety of ideas about the how, what and why of sketching. This ranges from casual observations to systematic description (Garner, 1990). Introspective methods formed in the 19th century the basis for the scientific revolution that led to the study of mental processes in psychology.

Many psychologists, however, have questioned the validity of introspection as the most objective way of studying mental processes. Objections to the use of this method have been raised in particular for the type of discoveries presently discussed. Metcalfe (1986; Metcalfe & Wiebe, 1987) argues that the time period preceding such a discovery (the incubation period; Wallas, 1926; Hadamard, 1945; Koestler, 1975; Poincaré, 1982; and recently Solso, 1991) is not open to introspection. The wide variety and lack of systematicity in self-reports may reflect these problems. It is possible that these self-reports reflect whichever ideology the artist happens to believe. In an attempt to characterize these beliefs, Boden (1990) distinguished two types: inspirational beliefs, reflecting a Platonic notion of insight as the discovery of an eternal idea (Rothenberg & Hausman, 1976), and romantic beliefs, stressing the uniqueness of artistic and scientific talents.

The scorned method of introspection is not to be confused with another method, which has been considered useful for the study of creative discovery processes. This method
collects and analyzes think-aloud protocols. Think-aloud protocols are self-reports which differ in an important way from introspection. A think-aloud protocol is collected during a process of creative discovery instead of afterwards. Therefore, the protocol is a direct verbalization of the ongoing process, in which self-reflexive expressions are discouraged.

This latter approach suffers from the fact that most creative processes extensively make use of visual thinking, or, in other words, there is a strong contribution of visual imagery. These processes are not accessible to direct verbalization. As Shepard put it "... it seems reasonable that the most novel ideas and radical departures from traditional ways of thinking are not likely to arise within the very system of verbal communication that is the primary vehicle for maintaining and perpetuating established ideas and entrenched traditions" (Shepard, 1978, p. 156). Protocol analysis, therefore, is not appropriate to reveal this particular kind of processes (Ericsson & Simon, 1980; Elshout & van Leeuwen, 1992) and might even obstruct them (Brandimonte, Schooler, & Gabbino, 1993; Schooler, Fallshore, & Fiore, 1995; Wilson, Lisle, Schooler; Hodges, Klaaren, & Lafleur, 1993).

The third way of approaching the question is the experimental method. This approach cannot easily address the problem directly, as creative processes are notoriously unpredictable (Hadamard, 1945). For this reason, the experimental method attacks the question by inverting the problem. For instance, for the problem what sketching contributes to the creative process, instead of raising the question why sketching is useful, the question is raised, what limitations do the mental processes have, such that sketching is needed. This strategy is employed in the present dissertation.

The search for limitations in processing has been pioneered by Anderson and Helstrup (1993ab, 1995). They proposed resource limitations to be the decisive impetus for sketching. Resource limitations, for example, are encountered when memory fails to keep track of a growing information load. In their experiments, however, these authors failed to obtain support for a crucial role of resource limitations in sketching.

An alternative approach has been taken in the present study. This approach rests on the idea that, since imagery plays an important role in the creative process, the limitations are to be found in imagery. In this view, the mental operations leading to discovery are viewed as a set of operations on a mental image. Sketching is needed if the operations cannot be done within imagery alone, or if the operations are much easier to perform externally.

This approach draws the attention away from the externalization itself and focuses on the mental processes preceding the sketching activity. Once these processes are understood, this will lead to insight in the origin and function of externalization.

The psychological literature on discovery in imagery has studied several different imagery processes. Some of these are easy and frequent; others are difficult and rare. The latter type being candidates for externalization support, if they are required for discovery. The fact that some processes in imagery were found to be difficult and others were hard, has led to a controversy in the literature before it was realized that two different types of processes may exist. Opposing conclusions were drawn on the one hand by Chambers and
Reisberg (1985) and Reed (1974) and on the other hand by Finke and Slayton (1988).

Chambers and Reisberg (1985) showed in their experiments that subjects were unable to reverse the interpretation of an ambiguous figure (e.g. duck/rabbit) in mental imagery. Subsequent investigations (Hyman & Neisser, 1991; Peterson et al., 1992) with a similar paradigm did not find completely zero performance, but discovery performances remained strikingly low. Such a reversal is easily performed if the figure is visually presented (See Figure 1.1). Reversal involves the discovery of an unanticipated structure. Chambers and Reisberg's (1985) results, therefore, argue for limitations on discovery in imagery, as compared to visual perception, and hence for a major role for sketching in discovery.

![An example of an ambiguous figure. The figure could be interpreted either as a dog or as a chef, and was used as stimulus by Chambers and Reisberg (1985) to show that reversal in imagery meets considerable difficulties.](image)

**Figure 1.1.** An example of an ambiguous figure. The figure could be interpreted either as a dog or as a chef, and was used as stimulus by Chambers and Reisberg (1985) to show that reversal in imagery meets considerable difficulties.

Similar restrictions on imagery were obtained by Reed and Johnsen (1975). They showed that the extraction of an unanticipated component is difficult in imagery, as compared to visual perception. These authors used a part-whole detection task. In this task, a figure is presented, followed by another one. The subject of the experiment must decide if the second is contained as a part of the first. Percentages correct answers and reaction times reflect the accuracy of processing.

With these tasks, it can be shown for perception that certain parts are more easily perceived as components of the whole than others. This depends on which parts are seen as building blocks of the structure of the whole. Usually, a whole is perceived as a unique composition of parts, although it is possible in principle to see it as composed in an alternative way as well (Figure 1.2). Reed and Johnson showed that the alternative composition was not recognized in imagery.
Figure 1.2. An example of a configuration and several alternative interpretations of its components.

Chambers and Reisberg (1985) used a task which involved imposing a new structure on old components of a figure. Reed and Johnsen (1975) involved the identification of new components in a structure. Both experiments, therefore, involve conditions in which subjects start from a given, structured pattern. The task requires them to break up this structure. From these experiments, the hypothesis can be drawn that imagery faces considerable difficulty in restructuring the initial conception of a pattern, and hence to discover new information in a mental image. In further discussing restructuring, it will be identified as a form of analysis.

Opposite conclusions on the issue of discovery in imagery were reported by Finke (Finke & Slayton, 1988; Finke, 1990). These authors asked subjects to synthesize simple elements into a recognizable object before their inner eye. For example, a letter “I” and a letter “D” can form an umbrella. They found that subjects were able to create and discover new unanticipated objects.

It could be observed, however, that Finke’s task does not require restructuring. The structure of the elements as initially given remains intact. In the umbrella example this means that the component structure of each letter “I” and “D” is not violated. Therefore, the processes involved in Finke’s figural combination tasks differ essentially from those involving analysis. The processes observed by Finke, which are easily performed in imagery, are called synthesis.
Therefore the opposing conclusions from the imagery literature can be reconciled on the assumption that two forms of processing in imagery have to be distinguished, viz. analysis and synthesis. The two different experimental paradigms, familiar from the literature, involve analytic and synthetic processes to different degrees.

The precious value of making things visible through sketching has been pointed out for Chambers and Reisberg's ambiguous figures. (Chambers & Reisberg, 1985). If the processes of synthesis and analysis impose different loads on imagery, different effects of paper-and-pencil support can be expected. If the imagery task is easy, as in the figural combination task (Finke), minor effects are expected. If the imagery task is difficult because of analysis, sketching is expected to enhance performance in the novel decomposition task (Reed).

The differences between the two experimental paradigms allow for this possibility. In two series of experiments this hypothesis was tested. The first series used a novel decomposition task (Verstijnen et al., submitted-a), and will be discussed in Chapter 2. The second series used a figural combination task (Verstijnen et al., submitted-b), and will be discussed in Chapter 3.
CHAPTER 2

Sketching in an Analysis Task

Abstract

Discovery of visual information in a mental image with and without the aid of sketching was investigated in three experiments. Novice sketchers were compared to experts. Subjects were briefly presented a set of overlapping simple geometrical figures, and were asked to decide whether a target was a part of the configuration. Positive targets could be explicit parts (items from the set), or implicit ones (resulting from the overlap). Implicit target detection was predicted to be troublesome in imagery and therefore sketching was expected to enhance performance. The first experiment forced one half of the subjects to sketch on every trial and denied this strategy to the other half. In the second and third experiment spontaneous sketch behavior was observed. The third experiment controlled for effects of memory load. When no sketching took place both experts and novices performed at chance-level on implicit targets, and well above chance-level on explicit targets. When (spontaneous) sketching took place, performance on implicit targets was raised for experts only. For both groups sketching did not raise the performance on explicit targets. It is argued, on the basis of these results that implicit information detection processes could explain the divergent findings in literature on discovery in imagery.
Introduction

Some of the most celebrated innovators in science (e.g. Einstein, Kekulé) as well as other creative individuals have claimed that their discoveries are a product of mental imagery (Shepard, 1978; Hadamard, 1949). Some support for the claim that discoveries are made in imagery can be found in the experimental literature. Finke and Slayton (1988), for instance, showed that if subjects combined in imagery certain elementary forms, they were able to recognize their invention afterwards (Finke, 1990). Figure 2.1 shows an example of such an invention made in imagery resulting from the instructions to combine a cone, a di-pyramid and a flat square (from Verstijnen, Goldschmidt, van Leeuwen, Hamel, & Hennessey, submitted-b.; after Finke & Slayton, 1988).

![Image of an object made with the Finke paradigm](image)

**Figure 2.1.** An example of an object made with the Finke paradigm (from Verstijnen et al., submitted-b.). The object is designed to wake (deaf) people up by placing it on/aside the pillow; it will start to rotate at wake-up time.

In Anderson and Helstrup (1993ab), with a similar task, subjects combined in imagery three simple shapes. The combination had to result into recognizable objects (after the instructions of Finke & Slayton, 1988) or creative ones (after Tarrant, 1993). Recognizability and creativity of the objects produced were scored by different judges. Half the subjects were allowed to sketch during this process. The sketch-group was compared to a non-sketch control group. Anderson and Helstrup (1993ab) found equal performance for both groups on recognizability as well as creativity. It could be concluded that this form of discovery in imagery is easy and therefore does not profit from paper and pencil support.

Chambers and Reisberg (1985), reached opposite conclusions about discovery in their studies. In their experiments subjects were unable to discover the opposite interpretation of a perceptually ambiguous pattern in imagery. For instance, when Jastrow's duck/rabbit (Jastrow, 1900, see Figure 2.2) was presented as a duck, subjects were unable to discover the rabbit interpretation from their image. Although subsequent studies did not show zero-level performance on this type of task, performance remained strikingly low (Hyman, 1993; Peterson, Kihlstrom, Rose, & Glisky, 1992; Reisberg & Chambers, 1991). After sketching the image, however; these subjects discovered the alternative interpretation from their sketches. Enactment (sketching) seems to be needed for this form of discovery.
Figure 2.2. Jastrow's duck/rabbit (Jastrow, 1900). Test stimulus employed by Chambers and Reisberg (1985).

In order to reconcile these opposing findings, it may be argued that two types of discovery could be distinguished. One type, predominant in Finke's studies (Finke & Slayton, 1988; Finke, 1990) is easy and frequent and can be performed in imagery without sketching; the other, as suggested by Chambers and Reisberg experiments (Chambers & Reisberg, 1985; Reisberg & Chambers, 1991), is difficult and rare and can be facilitated by sketching.

There are, however, numerous contrasts between the two paradigms preventing that such a conclusion could be drawn from the experiments so far. These contrasts make it difficult to infer, which aspect of discovery is difficult to perform in imagery. Comparing different imagery conditions within a single paradigm, could therefore be useful to specify the differences between these imagery processes. A hypothesis concerning the locus of the difficulty in processing in imagery is tested in the three experiments presently presented.

Our hypothesis is suggested by comparison of visual imagery and perception. In Reed and Johnsen (1975), for instance, simple line drawings like in Figure 2.3 were visually presented. Figure 2.3 is predominantly seen as composed of two hour-glasses. This drawing could also be interpreted, however, as construed of two overlapping parallelograms. The parallelograms could be said to be implicit information in the original line drawing, because they do not form part of the perceptually predominant structure. Whereas subjects find it easy to decide on this implicit information in the presence of the stimulus, they find it particularly difficult to do so in its absence. Reed and Johnsen (1975) concluded that detection of implicit information is difficult in imagery as compared to visual perception. (See also Hinton, 1979).
Figure 2.3. Pattern used by Reed and Johnsen (1975). If the parts (e.g., hourglasses) do not form part of the perceptually predominant structure (e.g., overlapping triangles), discovery of these parts is difficult in imagery in mental imagery.

In Finke and Slayton's shape combination task (1988), where the imagery task was found easy, the task was to provide a novel synthesis. No novel decomposition was needed to combine parts to a new whole in imagery. In Chambers and Reisberg's (1985) reversal experiments, the image needs to be restructured in order to identify the novel components which constitute the opposite interpretation of an ambiguous figure. For instance, the nose of the rabbit in Figure 2.2 is a novel component with respect to the earlier duck-interpretation. Whereas a novel decomposition violates the original decomposition in parts, novel synthesis leaves the original decomposition intact. For this reason, novel decomposition is proposed as a major source of difficulty in imagery processes.

It is important to note that a hypothesis based on novel decomposition does not conflict with the findings of Finke, Pinker and Farah (1989). These authors instructed their subjects to imagine, for example, a capital Q and subsequently put a capital O next to it on the left, and next to remove the diagonal line of the Q and finally rotate the pattern by 90 degrees to the left. The subjects easily detected the resulting image of a number 8. The original decomposition in parts in this case is not simply the capital Q and the capital O. It is common knowledge that a Q consists of two parts; a circle and a diagonal line. The original decomposition of the Q is not violated by removing the diagonal line. In general no novel decomposition is required to fulfil this task.

The present study will test the hypothesis that novel decomposition makes imagery difficult. This would be sufficient to explain the contrast between Finke and Slayton's (1988) shape combination and Chambers and Reisberg's (1985) reversal experiments. To test this hypothesis, subjects must detect the presence of components in their image. These components in some conditions were ones that are explicit parts of the perceived structure of the pattern. In this case detecting the components will be easy. In the other conditions, the detection of the components (implicit parts) required a novel decomposition. In this case, the detection in imagery will be hard.

It is therefore predicted that in a task requiring novel decomposition, subjects will benefit from sketching, whereas in the conditions where no novel decomposition is required,
they won't. This hypothesis is suggested by the analogy with perception and on our interpretation of Chambers and Reisberg's (1985) findings.

Anderson and Helstrup (1993ab) found no effect of sketching in a Finke paradigm. Given the hypothesis, the reason could be that this type of task requires no novel decomposition and therefore could easily be performed in imagery. To test whether the surplus value of paper and pencil support for imagery will show up only in the novel decomposition condition in Experiment 1, half of our subjects were compelled to sketch, the other half were not allowed to sketch. An additional reason why Anderson and Helstrup (1993ab) found no effect, could be the expertise of their subjects. It is possible that only expert sketchers are able to raise performance by their sketches. Novice's sketches may simply be too inaccurate as a result of lacking drawing skills. Experiments 1 and 2 will both compare two groups, expert and novice sketchers, to investigate whether experts are able to raise performance better than novices.

If novices are not adequate enough in sketching, it is possible that differences between novices and experts could be explained, solely on the basis of a lack of reliance on a sketching strategy by novices. As Experiment 1 compelled both groups to sketching, we need to know whether subjects differ in their spontaneous preference for sketching. It is suggested (Reisberg and Logie, 1993) that in this case the deficiency of imagery is felt by the subjects and they will spontaneously use an enactive strategy such as sketching. Experiments 2 and 3 therefore studied spontaneous sketching behaviour. Experiment 2 uses the same procedure as Experiment 1, except that subjects themselves may choose, whether they use paper and pencil. If it is predicted that a difference between experts and novices does not depend on the motivation to sketch, it is, by consequence, predicted that if a novel decomposition has to be made in imagery, both experts and novices will show spontaneous enactment (sketching), regardless of whether their performance is raised by doing so.

Effects obtained in Experiments 1 and 2 could alternatively be explained on the basis of memory load. If memory load rather than novel decomposition is decisive, the number of components will determine whether sketches are made. Experiment 3, therefore, is aimed at the influence of short-term memory load on the predictions by varying the number of components in a configuration.
Experiment 1

Method

Subjects. A total number of 46 subjects participated in this experiment, half of them (13 female and 10 male) were undergraduate psychology students from the University of Amsterdam and had no drawing skills, hence they will be listed as novices in sketching. The mean age of these novice sketchers was 22.19 years, varying between 18 and 39 years. These subjects received course credit for their participation. The remaining 23 subjects (also 13 female and 10 male) were industrial design engineering students from the Delft University of Technology. Their mean age was 22.34 years, ranging from 21 to 26 years. These subjects received a financial reward for their participation. Because of their intensive training in paper and pencil sketching these subjects will be called experts sketchers. Although drawing skills are required throughout their whole design study, the minimal requirement for admission to the experiment for experts having participated in at least two drawing courses.

Apparatus and Stimuli. Instructions and trials were presented on a 12 inch computer screen (Apple Macintosh LC). The viewing distance was about 40 centimetres, approximately 6 degrees of visual angle. Responses were made with mouse-clicking only; the keyboard had been removed.

Thirty unique configurations were constructed. Each configuration contained three of the five wire-frame forms shown in Figure 2.5: diamond, square, isosceles triangle, right-angled triangle or circle. Rotation of the wire-frame forms of Figure 2.5 in steps of 45° clockwise and counter-clockwise was applied to generate variation in the configurations. An example of a configuration is shown in Figure 2.4.

Sixteen of the 30 configurations were used for presentation in combination with an explicit target. Explicit (E) targets were any of the wire-frame forms (diamond, square, isosceles triangle, right-angled triangle or circle) used to construct the set of configurations. E targets which were part of the configuration are referred to as E; the remaining ones as E. Eight E, and 8 E, targets were selected for the experiment.

By combining the wire-frame components of Figure 2.5 into configurations, novel, implicit components result in each configuration (see Figure 2.7). These implicit (I) components are the closed figures that are the product of intersecting line segments of the original components. Only convex I components were used as targets. Fourteen configurations were used for presentation in combination with an I target. Implicit targets that are part of the configuration on a certain trial are referred to as I,. Implicit targets from other possible configurations, not shown on this particular trial, are referred to as I,. Seven I, and 7 I, targets were selected for the experiment.
Figure 2.4.  An example of a stimulus configuration, consisting of three wire-frame forms (square, diamond and triangle).

Figure 2.5.  The five possible geometrical components in the configurations.

The configurations were standardized in two respects. First, restrictions were imposed on the relative positions of the components in the configuration. Component wire-frames forms had to be aligned either with respect to their edges or with respect to their centres. In Figure 2.4, for instance, the rightmost edge of the right-angled triangle is aligned to the lower-right edge of the square. The centre of the diamond is aligned to the centre of the square.

The second standardization regards the size of the components. A fixed standard length was chosen for all wire-frame forms as indicated by the arrows in Figure 2.6. Both standardizations were used for the purpose of facilitating the reproduction of the image by the subject.
Figure 2.6. Illustration of the “Standard Length”. Once one of the components of a configuration was drawn, subjects could use this “Standard Length” to adapt the size of the other components and hence the reproduction of a configuration was facilitated.

Figure 2.7. Illustration of a stimulus configuration and its possible targets. This particular configuration was followed by target $I_Y$, an implicit target resulting from overlapping components.
Procedure

Subjects were informed that they were participating in a memory experiment. One half of the subjects were told to sketch the stimulus on every trial, even if they knew the correct answer right away. This condition will be called the “with-sketch” condition. The remaining subjects in the “without-sketch” condition were denied this strategy. The with-sketch group got paper-and-pencil supply. For experts, the with-sketch condition included 11 subjects (5 male and 6 female), and the without-sketch condition 12 subjects (5 male and 7 female). For novices, the same distribution of subjects over conditions applied; 11 subjects (also 5 male and 6 female) in the with-sketch condition and 12 subjects (also 5 male and 7 female) in the without-sketch condition.

The instructions made the subjects familiar with the five possible wire-frame forms and emphasized their standard length. The instructions were followed by an example of a configuration to familiarize them with the stimuli. After the instructions, the subjects got two practice trials, during which they could ask the experimenter questions.

Each trial consisted of a five-seconds presentation of a configuration, followed by a three digit number on the screen. Subjects were instructed to count backwards from this number in steps of three. This counting took one minute, during which a fly criss-crossed the screen to erase possible after-images of the stimulus. After this minute of counting backwards the target appeared on the screen. In order for the target to be a true part of the configuration, the target had to match the original in orientation as well as size. After the onset of the target, unrestricted time was given to the subjects to decide whether this target was a part of the configuration. The with-sketch group had to provide an answer only after finishing their sketch of the entire stimulus configuration, as far as they were able to reproduce it (this lasting about 60 seconds). During this phase, the target remained on the screen. Subjects initiated their response by a mouse click, whereafter two buttons appeared on the screen immediately; they could indicate their answer by clicking the ‘YES’ or ‘NO’-button.

The correct answer was displayed at the end of each trial in bold lines if the target had been present. The target was shown aside the configuration, if the target was not a component of the configuration. Figure 2.8 outlines the order of events in one trial. Each subject received the total of 30 trials (consisting of 8 EY + 8 EN + 7 IY + 7 IN targets) in random order.

The experiment was followed by a small paper folding (punched holes) test measuring visualisation ability as reported in Ekstrom et al. (1963), lasting 6 minutes and Kunzendorf’s aesthetic preferences test (Kunzendorf, 1982). This latter test measures the mastery of “visual grammar”. Creative individuals, according to Kunzendorf (1982), have a better mastery of “visual grammar”, which improves their ability to transform and restructure knowledge.
Figure 2.8. Illustration of the time course of a trial. At the beginning of a trial the stimulus is presented for a period of 5 seconds (A). This period is followed by one minute of counting back by three from the number that appeared on the screen. A fly criss-crossed the screen to erase afterimages of the stimulus (B). Hereafter a target appeared (C). Subjects could either get an implicit target (i.e. resulting form overlap of the primitive forms) or an explicit target (one of the primitive forms). For both types of targets existed true and false instances. While the targets remained on the screen the with-sketch subjects had to make use of paper and pencil in order to determine whether the target formed part of the stimulus (D). When the subjects reached an answer, they could end the presentation of the target by pressing the mouse button. A screen appeared (E) were they could indicate their answer. A trial ended with corresponding feedback (F).

Results

Mean percents correct on explicit trials ($E_T = E_Y + E_N$) were equal for novices and experts in the without-sketch condition (resp. 73.44%; Std.Err.$= 2.79$ vs. 70.83%; Std.Err.$= 5.01$; $T(22) = 0.455; p = .654$), as well as in the with-sketch condition (resp. 79.55%; Std.Err.$= 2.68$ vs. 80.53%; Std.Err.$= 2.49; T(20) = 0.269; p = .790$). For both novices and experts, the differences between the without-sketch and with-sketch condition were not significant (resp. $T(21) = 1.575; p = .130$ and $T(21) = 1.685; p = .107$).

Percents correct on implicit trails ($I_T = I_Y + I_N$) show a different pattern. Mean percents correct on these trials show a nonsignificant difference between novices and experts in the without-sketch condition (resp. 55.38%; Std.Err.$= 4.04$ vs. 54.02%; Std.Err.$= 1.78; T(22) = 0.304, $p = .764$), but a significant difference in the with-sketch condition (resp. 61.04%; Std.Err.$= 3.25$ vs. 74.42%; Std.Err.$= 2.15; T(20) = 3.434; $p = .003$). Whereas novices in the with- and without-sketch group do not differ significantly on implicit targets ($T(21) = 1.083; p = .291$), for the experts these conditions differ significantly ($T(21) = 7.34, p = .001$). Figure 2.9 shows the mean percents correct for novices and experts.
Figure 2.9. Illustration of the mean percentages correct of novice sketchers and expert sketchers of Experiment 1. The mean score on implicit targets of experts allowed to sketch (with-sketch group) shows on the one hand a significant difference with the mean score on these implicit trials of experts not allowed to sketch (without-sketch group), and on the other hand a significant difference with mean percentage correct on implicit targets of the novices not allowed to sketch. No other significant differences are found.

For experts in the without-sketch group, the percent correct on $E_T$ showed a significant negative correlation with percent correct scores on $I_T$ ($r = -0.696, T(10) = 3.065, \ p < .01$), this value was $.008$ (n.s.) for novices. The with-sketch groups showed correlations of $.326$ (n.s.) for the experts and $.157$ (n.s.) for the novices. So, without sketching experts performed better on $E$ targets than on $I$ targets or vice versa. Many experts reported frustration by not being allowed to sketch. No frustration was reported by novices. Frustration may explain the negative correlation for experts; not being able to sketch, some of the experts reported being torn between the opposing strategies of selectively attending either $E$ or $I$ targets.

With respect to the presence ($E_Y$ and $I_Y$) or absence ($E_N$ and $I_N$) of targets it was found that both experts and novices in the with-sketch group performed similarly on $E_Y$ and $E_N$. However, for both groups, percent correct scores on $I_N$ were significantly higher than on $I_Y$ (experts: $I_Y = 56.27\%$, $\text{Std.Err.} = 3.79$ and $I_N = 92.21\%$, $\text{Std.Err.} = 2.25$; $T(10) = 8.401$; $p < .01$, novices: $I_Y = 40.26\%$, $\text{Std.Err.} = 5.72$ and $I_N = 81.82\%$, $\text{Std.Err.} = 4.35$; $T(10) = 5.319$; $p < .01$). This might suggest that both experts and novices had a preference for answering NO on $I$ targets. Because the percentage correct measure included equal numbers of positive and negative trials, such preferences could not explain the improved results for the $I$ targets as an effect of sketching.
No significant differences between female and male subjects could be established for any of the experimental variables.

The mean scores on the punched-holes test of novices and experts were respectively 14.48 (Std.Err. = .829) and 15.83 (Std.Err. = .592) (a non significant difference; T(44) = 1.323, p = .193). For novices in the without-sketch condition, the correlation of the punched-holes test with percentage correct on I and E targets is respectively -.027 (n.s.) and -.089 (n.s.). For experts in the without-sketch condition these values are respectively -.332 (n.s.) and .288 (n.s.). Within the with-sketch conditions these values are respectively .172 (n.s.) and .559 (T(9) = 2.023, p < .05) for the novices, and .338 (n.s.) and .244 (n.s.) for the experts. So, only for novices in the with-sketch condition a relation could be established for the punched-holes test and percent correct on E targets only.

Scores on Kunzendorf’s aesthetic preference test did not differ significantly. Within each group no significant correlations of the Kunzendorf test with any of the experimental variables could be established.
Experiment 2

Method

Subjects. 44 Subjects took part in this experiment, none of them took part in Experiment 1. 21 Of them were novice sketchers, 13 female and 8 male, again drawn from the population of undergraduate psychology students from the University of Amsterdam, their mean age was 22.19 years (ranging from 18 to 29 year). They received course credit for their participation. The same requirements as in the first experiment were imposed on expert sketchers: at least having participated in two drawing courses. All experts, 9 female and 14 male, were again drawn from the population of Industrial Design Engineering students of the Delft University of Technology. They received a financial reward for their participation, their mean age was 22.34 (ranging from 20 to 26 years).

Stimuli. The stimuli were identical to those of the first experiment.

Procedure

Subjects were told they were participating in a memory experiment and were kept uninformed of the fact that their sketching behaviour was videotaped and analyzed. The procedure in the second experiment was generally identical to the one used in the first experiment (see Figure 2.8) except that in this experiment the subjects were not compelled to sketch but could use the paper and pencil if they wanted to (correspondingly, in Figure 2.8, stage D should be read as “while target on screen: pencil and paper supply”, with the understanding that their use is not compulsory). Again they were not allowed to use paper and pencil before the target was presented on the screen. The subjects in this experiment were submitted to more pre- and post-tests, so two sessions per subject were required. In the first session the following pre-tests were administered: Raven’s Advanced Progressive Matrices (Raven, 1988), visual STM-span (Visual Number Span Test; Ekstrom, French, & Harman, 1976), Witkin’s Embedded Figures test (Witkin, Oltman, Raskin, & Karp, 1971), Marks’Vividness of Visual Imagery Questionnaire (VVIQ; Marks, 1973) and, like in the first experiment, Kunzendorf’s aesthetic preferences test (Kunzendorf, 1982). In the second session the experiment took place, lasting about 45 minutes.

Scoring

Each session was videotaped; on each trial, if any sketching was observed, the trial received a sketch score of 1, otherwise the score was 0. If at least one line was drawn on a trial it was registered as sketching. The maximal sketch score of a subject over 30 trials
would therefore be 30, but occasionally it was uncertain if sketching took place. These trials were left out from the analyses of a subject. Percent sketch and percent correct over all remaining trials was calculated.

**Results**

Both groups of different levels of expertise show more sketching behavior when asked for I targets than for E targets. Mean percent sketch on I targets was 52.26% (Std.Err.: 7.24) for novices and 67.40% (Std.Err.: 6.82) for experts, on E targets these mean scores show values of 31.38% (Std.Err.: 5.56) and 37.99% (Std.Err.: 5.86) respectively, see Figure 2.10. A T-test on difference scores I\_\text{F} percent sketch minus E\_\text{F} percent sketch per subject for both experts and novices together shows a significant deviation from zero (T(43) = 7.352; p < 0.0001). This difference in sketch rate applies also to both groups separately; T(20) = 3.765; p < 0.001 for novices only and T(22) = 7.172; p < 0.0001 for experts only. These differences are equal in size for the two groups; T(42) = 1.403; p = 0.168.

For novices, the correlation of individual scores on percent sketch on I\_\text{F} with percent correct on I\_\text{F} shows a nonsignificant value of .221. For experts, this correlation raises to .715, T(21) = 4.687; p < 0.0001. These two correlations differ significantly; Z = 2.075, p < .05. Figure 2.11 illustrates these different correlations. From this result it can be concluded that although both novice and expert sketchers start sketching to find the implicit information in request, only the latter group was able to discover the correct answers from their drawings.

**Figure 2.10.** Mean scores and error bars of percent sketch on implicit and explicit targets for novices and experts. The graph shows that significantly more sketching took place when subjects were asked for implicit information.
For both groups the correlation of percent correct on explicit targets with percent sketch on these targets (E₁) is not significant, i.e. -.047 for novices and -.034 for experts.

![Graph showing correlation between percent correct on explicit targets and percent sketch on implicit targets for novices and experts.](image)

**Figure 2.11.** Illustration of the correlation between individual scores on percent correct on I₁ (I₁-%correct) and percent sketch in I₁ (I₁-%sketch) for both novices and experts. It shows that only experts profit from their sketches in finding the implicit information in request.

The regression lines of the data of Experiment 2 in Figure 2.11, yield for a hypothetical 100% of sketching on I₁ (I₁-%sketch = 100%) a value of 78.23% correct for experts and 63.55% for novices. Experiment 1 yielded a value of 74.42% correct for expert sketchers and 61.04% for novices in the with-sketch group (I₁-%sketch = 100%). The regression line in Figure 2.11 yields for a hypothetical I₁-%sketch = 0% values of 54.39% for novices and 43.66% for experts. The without-sketch (I₁-%sketch = 0%) groups of Experiment 1 yielded comparable percents correct on I₁ of 55.38% for novices and 54.02% for experts. The results of this experiment are in accordance with the results of Experiment 1.

For experts, the relation between discovery rate of implicit targets and sketching turned out to be related to individual creativity as measured with Kunzendorf’s (1982) aesthetic preferences test. For the 7 lowest scores on this test this correlation is .035, for the 7 highest scores this correlation reaches a value of .936. Moving a window of width 7 scores across the ascending creativity scores by steps of one (the 7 lowest scores, i.e. creativity scores with rank 1 to 7 fall in Window 1, ranks 2 to 8 fall in Window 2, ranks 3 to 9 in Window 3, and so on till the 7 highest scores in Window 18), results in a sequence of
correlations between I-%sketch and I-%correct. A rank correlation between this correlations and the window number (1 to 18) can be computed. This correlation reaches a value of .654 (total number of windows = 18, T(16) = 3.458; p = 0.003). This correlation of correlations shows that creativity is a modulating factor between sketching and discovery; such a relation is more predominant in creative subjects than in less creative ones. For this reason, the present measure is preferred over calculation of a partial correlation, which would have misleadingly suggested an equal influence of creativity across the whole range of the other variables.

This three-way relation between creativity, sketching and percent correct in the case of experts can also be observed by restricting the analysis to those I target trials in which sketching took place; the correlation between discovery of the target in these trials and creativity scores shows a significant value of .488 (T(21) = 2.576; p < .01). In contrast, no such correlation existed for novice sketchers. A possible explanation why this effect was observed in this experiment and not in Experiment 1, will involve the spontaneous and thus more natural character of sketching in this second experiment.

For both experts and novices the presence (IY) or absence (IN) of an I target did not contribute to the rate of sketches produced: the mean number of sketch observations is comparable, (for experts the mean percent sketch on IY is 67.91% (Std.Err. = 7.31) and on IN 66.77% (Std.Err. = 7.12); T(22) = 0.242; p = 0.811, for novices the means are respectively 56.01% (Std.Err. = 7.37) and 51.79% (Std.Err. = 7.65); T(20) = 0.707; p = 0.488), suggesting that presence or absence of an I target was barely detectable before sketching.

The presence (Ey) or absence (EN) of an E target in a configuration, however, did contribute to the number of sketches made, resulting in a significant difference in mean number of sketches (mean percent sketch on Ey and EN being respectively 29.74% (Std.Err. = 4.81) and 46.20% (Std.Err. = 7.26) for expert sketchers; T(22) = 4.286; p < 0.001, for novices respectively 24.01% (Std.Err. = 5.77) and 38.03% (Std.Err. = 5.78); T(20) = 4.050; p = 0.001). Both groups made more sketches on EN than on Ey. This difference illustrates that subjects, in contrast with the I targets, had a feeling of knowing about E targets before they started sketching. The difference is probably caused by uncertainty about having forgotten whether this particular component belonged to the configuration. Like in Experiment 1, gender was not found to affect the experimental variables.

Tables 2.1 and 2.2 show the correlations found between the experimental variables, (ET-%correct, I-%correct, ET-%sketch and I-%sketch) and the administered test scores, for novices and experts independently. The VVIQ didn't show any significant correlation with any of the dependent variables (see also Chara & Hamm, 1989; Ernest & Paivio, 1971) and hence, was left out of the tables. Note that the Embedded Figures test was filled in by 6 novices only.
<table>
<thead>
<tr>
<th>Novices</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Raven</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. STM</td>
<td>.291</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Emb. Figures</td>
<td>.700</td>
<td>.609</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Kunzendorf</td>
<td>.164</td>
<td>.088</td>
<td>.353</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. I-%sketch</td>
<td>.116</td>
<td>.005</td>
<td>.398</td>
<td>.480</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. E-%sketch</td>
<td>.142</td>
<td>.218</td>
<td>.744</td>
<td>.289</td>
<td>.661</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. I-%correct</td>
<td>.103</td>
<td>.120</td>
<td>.296</td>
<td>.201</td>
<td>.221</td>
<td>.215</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>8. E-%correct</td>
<td>.445</td>
<td>.330</td>
<td>.691</td>
<td>.053</td>
<td>.145</td>
<td>.047</td>
<td>.352</td>
<td>1.00</td>
</tr>
</tbody>
</table>

**Table 2.1.** Correlation matrix for novices only (n= 21).

<table>
<thead>
<tr>
<th>Experts</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Raven</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. STM</td>
<td>.382</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Emb. Figures</td>
<td>.679</td>
<td>.488</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Kunzendorf</td>
<td>.259</td>
<td>.176</td>
<td>.130</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. I-%sketch</td>
<td>.311</td>
<td>.017</td>
<td>.341</td>
<td>.291</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. E-%sketch</td>
<td>.011</td>
<td>.091</td>
<td>.157</td>
<td>.335</td>
<td>.801</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. I-%correct</td>
<td>.377</td>
<td>.223</td>
<td>.259</td>
<td>.390</td>
<td>.715</td>
<td>.663</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>8. E-%correct</td>
<td>.449</td>
<td>.380</td>
<td>.611</td>
<td>.148</td>
<td>.069</td>
<td>.034</td>
<td>.336</td>
<td>1.00</td>
</tr>
</tbody>
</table>

**Table 2.2.** Correlation matrix for novices only (n= 21).

Principal Component analyses (orthogonal transformation, varimax) on the above matrices in Table 2.1 and 2.2 (Embedded Figures Test by novices excluded), yield two main factors for both novices and experts. For experts 65.7% of the total variance is attributable to these two factors, for novices this value is 54.3%. One factor was loading high on Raven, STM, Embedded Figures (experts only) and E-%correct, and low on Kunzendorf, I-%sketch and E-%sketch. High scores on Raven, STM and Embedded Figures tests could indicate the ability to extract and retain for the duration of a trial, the wire-frame figures from which the configuration is composed. This factor was therefore labelled the "Smart"-factor.

The other factor loaded vice versa, that is, high on Kunzendorf, I-%sketch and E-%sketch, but low on Raven, STM, Embedded Figures and E-%correct, and hence was labelled the "Art"-factor.
Figure 2.12. Results from a Principal Component Analysis on the correlation matrix of novice sketchers. Factor 1 has been labelled the 'Art-factor', factor 2 the 'Smart-factor'. E-%correct and I-%correct are short for percent correct on E-targets resp. I-targets, ditto for %sketch.

Figure 2.13. Results from a Principal Component Analysis on the correlation matrix of expert sketchers. Factor 1 has been labelled the 'Art-factor', factor 2 the 'Smart-factor'. The main difference with the factor load graph of novice sketchers (Figure 2.12) concentrates on percent correct on implicit targets (I-%correct). In contrast with the novices sketchers, with expert sketchers the 'Art'-factor and the 'Smart'-factor co-operate on I-%correct.
The "Art" and the "Smart" factor loaded approximately 0 for novices on percent correct on implicit targets (I-%correct), see Figure 2.12. But for experts 76.84% of the variance of this variable was explained by these two factors, see Figure 2.13. For experts, the Art factor explained an approximately 5 times larger percentage of the variance than the Smart factor. So, whereas the Smart factor loads predominantly on subjects' percent correct score on the E targets, the Art factor loads predominantly on I target performance (for experts only).

The fact that scores on I-%correct do barely correlate with the tests that load predominantly on the "Smart"-factor, but have high correlations with the measure of sketch frequency, suggests that the bottleneck for correct answering on I targets lies at sketch level rather than at the ability to memorize the components of a configuration. This, although memorizing the components, must also be a prerequisite for the I targets.

Four judges, all expert sketchers, were reasonably accurate in splitting up the sketches into the ones produced by expert sketchers and the ones produced by novices (they achieved a mean of 70 % correct). The equivalent scores of novices and experts on all tests, in combination with these expertise judgements, suggests that the superior performance of expert sketchers on I targets concentrates in the ability to control the sketch gestures.

Only experts, who, per definition, possess the accurate apparatus for sketching, will therefore be able to overcome this bottleneck. In addition, the Principal Component Analyses also suggest that the 'smart' variables (Raven, STM, and Embedded Figures) dissociate from the 'art' variables (Kunzendorf's aesthetic preferences test, and the sketch measures), but only in the case of expert sketchers, the "Smart"-factor and the "Art"-factor co-operate to accomplish correct answers on implicit targets.
Experiment 3

One of the variables that had little influence on the percent correct on implicit targets was STM as measured with the Visual Number Span Test (Ekstrom et al., 1976). We felt that we had to re-establish this finding, because it will rule out the alternative explanation and the generally-held intuition of expert sketchers that sketching helps to keep up with the ever-growing memory load.

Method

Subjects. 18 Subjects took part in this experiment, 9 female and 9 male. None of them participated in the first or second experiment. They were all expert sketchers, that is, they all met the requirements for expertise as listed in the previous experiments. All subjects received a financial reward for their participation.

Stimuli. The subjects received 32 trials, of which 16 trials with E targets. These 16 trials were split up in 4 trials with configurations of 2 wire-frame components, 4 trials with 3 components, 4 trials with 4 components and the remaining 4 trials with 5 components. The other 16 trials contained configurations with implicit targets, also with 4 trials with 2 components, 4 trials with 3 components, 4 trials with 4 components and 4 trials with 5 components. Again half of the implicit and explicit targets was present, half was absent.

Procedure

The procedure was identical to that of Experiment 2. The experiment was followed by a small paper folding (punched holes) test measuring visualization ability as reported in Ekstrom et al. (1963), lasting 6 minutes.

Results

Figure 2.14 shows a flat slope of the mean percent sketching against the number of components. The number of components in a configuration did not influence the rate of sketching. This result argues against the alternative explanation for the results of Experiments 1 and 2, that the effects are due to memory load.

Combining across trials with different numbers of components in a configuration, the present experiment replicated the earlier obtained effects: mean sketching rate on E targets was 34.03% (Std.Err.= 7.75), on I targets 49.31% (Std.Err.= 9.04). The difference in
sketching rate was significant \((T(17) = 3.49; p = .003)\). Mean \(E_t\)-%correct was 64.94\% (Std.Err.: 2.95) and \(I_t\)-%correct 63.54\% (Std.Err.: 3.51). This difference in percentage correct was not significant \((T(17) = 0.44; p = .665)\).

Like in the previous experiments, sketching on \(I\) targets correlated significantly with percent correct on \(I\) targets, \(r = .488 \ (T(16) = 2.236; p = 0.041)\) and correlation between sketching on \(E\) targets and percent correct on \(E\) targets was nonsignificant, \(r = .100\). The mean score established on the paper folding test was \(17.56 \ (\text{Std.Err.:} .499; n = 18)\). The paper folding scores correlated significantly \((r = .563 \ (T(16) = 2.725; p < .01))\) with percent correct scores on \(I\) targets, but had no significant correlation with percentage correct on \(E\) targets, nor with any of the other variables. No differences were found between male and female subjects, as was found in the previous experiments.

From these results it could therefore be concluded that, at least for the range of complexity of the figures used in the present experiment, the number of components and the corresponding memory load had no influence on sketching behavior.

![Graph](image)

**Figure 2.14.** Scatter plot of the number of components in a configuration versus sketching (with a sketch being made on a trial scored as 1, no sketch scored as 0). Regression lines show that there exists no relationship between the number of components and the rate of sketching, they also show that more sketches are being made on implicit trials than on explicit trials.
General Discussion

Implicit targets, ones that don't form part of the image structure, lead to a chance-level performance when they have to be retrieved from imagery alone, i.e. without the aid of sketching. This is both the case for experts and novices and regardless of whether the abstinence of sketching was forced (Experiment 1) or spontaneous (Experiments 2 & 3). With the aid of a sketch, only experts could improve their accuracy. Positive and negative trials with implicit targets elicit an equal number of spontaneous sketches, suggesting that the mental image alone provides no cues on the presence or absence of these targets before sketching. Once a sketch was made, however, the experts could easily perceive the implicit information in their sketches. Externalizations of images, when skilfully made, can be helpful in making implicit information available.

In contrast, for explicit targets performance of visual imagery without the aid of sketching matched the performance with this aid, regardless of whether sketching was compelled (Experiment 1) or spontaneous (Experiments 2 & 3). Novices and Experts show equal performance in these conditions.

Experiment 3 showed that the information load on explicit targets did not influence the number of spontaneous sketches. This result eliminates an explanation for the sketching data based on short-term memory load. Subjects, in other words, turn to sketching not when faced with memory overload per se, but when faced with the difficulty of retrieving implicit information.

Our finding of auxiliary value of sketching extends Anderson and Helstrup's (1993ab) studies. These authors found no effect of sketching with novices. The present results, however, show in addition that experts differ in this respect from novices.

If only expertise would have been responsible for the sketching effect, an equal effect should have been found in experts for explicit targets as well. As this turned out not to be the case, it can be concluded that expertise contributes to performance only when implicit targets are sought for.

Our explanation is, that the imagery retrieval task is different for explicit and for implicit targets. Explicit targets can be obtained from the configuration without having to restructure the image (i.e. perform a novel decomposition). In order to retrieve the implicit target, however, a novel decomposition has to be performed.

Not all forms of processing in imagery appear to be as hard as novel decomposition. There are forms of discovery in imagery that are easy, as is suggested by Finke and Slayton (1988). Verstijnen et al. (submitted-b) showed with a paradigm comparable to Finke and Slayton (1988) that on a pure synthesis measure, not only do novices equally well as expert sketchers, also neither of these groups raises their performance through sketching. In combination with the effects obtained in Experiments 1-3, these findings suggest that only one form of processing is difficult to perform in imagery: novel decomposition. Novel
decomposition is a form of restructuring. Restructuring was considered the crucial factor for explaining the difference between the findings of Chambers and Reisberg (1985) who claimed that discovery in imagery is hard, versus Finke (1990) who claimed that discovery in imagery is fluent.

A possible explanation for the preference for synthesis (the Finke-task of combining components leading to a new and unanticipated form) over analysis (novel decomposition and more generally restructuring) may be sought in the important role of the visual system in visual imagery (Kosslyn, 1980). It has recently been claimed that the visual system has an intrinsic preference for synthesis over analysis (van Leeuwen, 1995). In this view, perceptual processing typically occurs by nonlinearly combining parts into wholes. Performing Analysis in a later stage of perception runs counter to this intrinsic tendency and is therefore infrequent in the laboratory (van Leeuwen & Bakker, 1995).

This view allows for the possibility that creative individuals are more likely than others to use this exceptional strategy spontaneously. From this viewpoint it is no surprise that individual creativity according to Kunzendorf's aesthetic preference test (Kunzendorf, 1982) was correlated with analysis. More creative expert sketchers, as measured by this test, were more likely to discover implicit targets in their spontaneous sketches.

In Kunzendorf's test (1982), creativity is understood as mastery of "visual grammar". This notion of creativity reflects an individual characteristic and stresses the flexibility in getting loose of current understandings and replacing them with other interpretations (comparable notions on creativity can for example be found in Indurkhy, 1992). The more creative an individual is, the more sensitive he/she is to alternative descriptions of a pattern. In our experiments creative individuals were able to restructure their sketches better and hence find the implicit targets easier than their less creative comperees. The fact that this effect is observed adds to the construct validity of this notion of creativity and the theoretical constructs on which it is based.

Contrasting roles of creativity in discovery may be traced back to the use of different notions of creativity. In Finke and Slayton's (1988) and Anderson and Helstrup's (1993ab) shape combination tasks, end-products were rated on creativity by judges. The criteria for creativity employed in these studies will presumably reflect the novelty or uniqueness of the end-product with reference to existing products (as known by the judges). Insofar this criterion reflects an underlying individual ability, it will mainly reflect the quality (novelty or uniqueness) of the established synthesis. Therefore, insofar individual characteristics of processing were evaluated in these studies, these were different from the ability to perform analysis, that proved relevant for our studies.

In Anderson and Helstrup (1993ab), factors relating to synthesis did not prove relevant for sketching. This, however, does not exclude that these factors play a role in the creative process. Often two processes are distinguished in creative imagery that appear to differ in their use of synthetic and analytic processing resources. The difference between synthesis and analysis as made in the context of the present experiments, however, does not map in a straightforward way on the process distinction made in the creativity literature.
For instance, Finke's Geneplore model, distinguishes *generation* and *exploration* (Finke, 1993; Smith, Ward, & Finke, 1995). Exploration is thought to exploit emergent properties. Emergent properties, however, can either result from synthesis (generation) or from restructuring (analysis). Since our studies show that analysis and synthesis play different roles in imagery, we propose to distinguish these processes as a basis for modelling imagery, creativity and discovery.
CHAPTER 3

Sketching in a Synthesis Task

Abstract

In three experiments, analytic and synthetic processing were contrasted in a figural combination task. The task was performed under imagery and sketching conditions. Novices were compared with expert sketchers on measures of analytic and synthetic processing. Whereas synthetic processing unrolled equally well in both conditions and expertise levels, more analytic processing was found for experts in sketching conditions. Creativity ratings of figural combinations made by expert sketchers, correlated highly with both synthetic and analytic processing in the sketching condition, but only with synthetic processing in the imagery condition. The results are in accordance with a model of creative processing, in which creative processes have both analytic and synthetic components, analytic processing being hard in imagery.
Introduction

Visual imagery research is moving towards an optimistic view on the possibility of using imagery for discovery. A major impetus for this shift in attitude originates from the seminal work of Finke and his colleagues. Finke and Slayton (1988) and Finke (1990; Finke, Pinker, & Farah, 1989) trained subjects on simple components such as a square, a circle, and an uppercase letter V, labelled with their names. Each subject then received the names of three components, which they were to combine into a single object in imagery. The square, the circle, and the letter V could, for example, be combined into an image of a television. Afterwards, subjects wrote down a description of the object they had conceived and provided a drawing. Descriptions and drawings were rated on creativity. Approximately 16% of the products were rated at the highest level of creativity, from which Finke concluded the possibility of making innovative discoveries in imagery.

Finke's initial research, however, didn't address the question how good performance in imagery is, when compared to external representation conditions. In subsequent studies (Neblett, Finke and Ginsburg (unpublished; reported in Finke, 1990) subjects were provided with transparent overlays containing the components. Half of the subjects were allowed to make a combination by moving around the overlays. This condition did not increase performance, as compared with synthesis in imagery. Although the imagery group was discouraged from bending or otherwise altering the figures, the subjects in this group had considerable more freedom to do this than the overlays group. Because doing so may be an essential part of the creative process, this additional freedom may have compensated for the disadvantage of not being able to use external support.

Anderson and Helstrup (1993a&b) applied a more natural external representation condition to Finke's figure combination task. Providing the subject with drawing facilities was expected to increase the number of creative objects. These authors, however, repeatedly found little or no effect of drawing support.

The fact that imagery-alone versus external support conditions yielded equally creative results still allows these conditions to differ in more subtle ways. Subjects may have drawn on different processing resources between the conditions, which the ratings failed to discriminate. Anderson and Helstrup (1993a&b) analyzed for this reason the end-products on what they called transformational complexity. To obtain a transformational complexity score for an end-product they summed size transformation, rotation, mirror imaging, and embedding of the components. Again a negative result was obtained; the score was found invariant between the internal and external conditions.

In adding up these various aspects of transformational complexity, the authors may have lost crucial information about imagery processes. One type of transformation in imagery may have been more prominent in one condition, and the other in the alternative condition. Two processes could be distinguished: synthesis and analysis. These processes may imply two distinct families of transformations (Verstijnen, van Leeuwen, Hamel, & Hennessey, submitted). In the synthesis process, the constituent structure of the components remains intact,
while the components are being joined into a more global whole. In the analysis process, the whole and its constituents parts are restructured. As a result, new unanticipated constituents may appear and old ones may disappear (novel decomposition), or constituents may undergo a transformation (e.g. a cube is transformed into a rectangular box).

Verstijnen et al. (submitted-a) showed that analytic processing in imagery is difficult, whereas under externalized conditions, analytic perceptual processing meets no obvious difficulties (see also Reed, 1974; Reed & Johnsen, 1975). Providing subjects with the possibility of externalizing their image through paper and pencil sketching substantially increased their performance on targets for whose discovery required restructuring.

Two of the four constituents of Anderson and Helstrup’s (1993a&b) transformational complexity measure, viz. mirror imaging and rotation, leave the structure of the components intact, and therefore represent synthetic processing. Size transformation, and maybe also embedding, alter the structure of the components, and therefore represent analytic processing (Verstijnen et al., submitted-a). The transformational complexity measure, thus, may have been insensitive to differences in the relative importance of analytic and synthetic processing between imagery versus sketching conditions.

In Finke’s figure combination task, the predominant process is likely to be synthesis, particularly because the subjects were not allowed to bend or otherwise alter the components. Given that synthesis is easy to perform without sketching, this may explain why no differences between imagery and external conditions are found. Yet, certain analytic aspects of the task could be facilitated with sketching: the proportional size of the components can be altered, e.g. cube becomes rectangular box; the relative size of the three components can be changed (on initial presentation they were similar in size); one component can be embedded in a second component, altering its structure; the components can be joined in such a way that an unanticipated penetration line occurs; normally, for instance, a sphere penetrates a plane leads to a circle as penetration line - when, however, the sphere penetrates the point of a pyramid, as in Figure 3.4E, a flower-like penetration line occurs; finally, a component may completely be modified, e.g. a sphere becomes a half-sphere (Figure 3.4F).

Although Finke’s figural combination task may be predominantly a synthesis task, we expect this task to have analytic aspects too. If so, more analytic processing traces are expected in the drawing-support conditions than in imagery-alone conditions. Synthetic processing will not benefit from externalization. It is even possible that externalization impedes on synthetic processing. The contribution of analytic and synthetic processes in the Finke task was therefore investigated in three experiments, comparing imagery (without-sketching) with externalization (with-sketching) conditions.

Verstijnen et al. (submitted-a) found that the analytic ability was related to individual creativity. Insofar as individual creativity is related to product creativity ratings in Finke’s task, these ratings are expected to be higher in sketching conditions. However, Verstijnen et al. (submitted-a) obtained an important restriction on the relation between analytic ability and creativity. The relationship was obtained only for expert sketchers, skilful in working with
external representations, but not for novices. This restriction may provide another reason for the null effects in Anderson and Helstrup’s studies, where only novice sketchers were investigated. For this reason, experts and novices were compared with each other in the present experiments.

The experiments investigated synthetic and analytic processing in Finke’s figural combination task. Experiments 1 and 2 used a slight modification of the original Finke task. A more restricted set of components was used, in order to facilitate comparison between subjects. Because of this difference in paradigm, a third experiment was conducted in which the original Finke task was used, and the subjects were experts.

If synthesis is easy and frequent, no increase in synthesis is expected as a result of sketching, neither for experts (Experiment 1) nor for novices (Experiment 2). If analysis in imagery is difficult, it will be more frequently found in the end-products of the with-sketch than those of the without-sketch condition. On the basis of Verstijnen et al. (submitted-a), this latter result is expected for experts only. Moreover, if analysis correlates with individual creativity (Verstijnen et al., submitted-a), expert sketchers in the drawing condition will receive higher creativity ratings for their end products.
Experiment 1

Method

Subjects. Sixty subjects (30 female and 30 male) took part in the experiment. All were Industrial Design Engineering students at the Delft University of Technology in the Netherlands. Mean age was 22.87 years, ranging from 21 to 28 years. They all completed their first two years successfully, hence each subject had received at least two years of drawing courses, and therefore can be considered expert sketchers. (See also Verstijnen et al., submitted-a, where the same selection criteria for expert sketchers were used). Subjects received financial reward for their participation.

Apparatus and Stimuli. Instructions and trials were presented on a 14" computer screen (Apple Macintosh Iicl). The viewing distance was about 40 centimetres. A cube, a cone, a flat square, a sphere, a cylinder, and a diamond (officially called a di-pyramid) were used as the components, from which the objects were to be constructed. The diamond is the only component not previously used in Finke's 3D-set of components (Finke, 1990). All these components existed in a wire-frame version (see Figure 3.1a), a flat-shaded one (Figure 3.1b), both of which were presented on the computer screen, and an actual version (Figure 3.1c) made of grey painted wood. The size, shape, and colour of these components were matched to those presented on the computer. Each component was labelled with its name. For auditory presentation during the experiment, the component names were recorded as samples of a female voice.

Prior to the experiment, eight unique triplets of components' names were selected. Each triplet contained three different names, and all names were used an equal number of times. Selection was random within these constraints, resulting in the following triplets: cube-square-cone / diamond-cube-cylinder / cone-diamond-cube / diamond-cylinder-flat square / sphere-cube-flat square / flat square-cylinder-cone / diamond-flat square-sphere / cylinder-cone-sphere.
Figure 3.1. The 3 possible forms of presentation of the components at about 30% of their original size. Original sizes: 16.9 cm * 22.6 cm. The wire frame components and the flat-shaded components were presented on a computer screen. Picture c contains a photograph of the actual components. In the pictures the names of the components are written in Dutch. Translated into English these names are (in reading order): diamond, cube, cone, flat square, sphere and cylinder.
Procedure

The experiment was announced as "Playing with Figures". Subjects were informed about the task by means of written instructions presented on the computer screen. They were shown the set of 6 possible components in one of the three alternative versions. One third of the subjects received the wire-frame components (Figure 3.1a) and one third received the flat-shaded components (Figure 3.1b), both presented as a picture on the computer screen. The instruction consisted of several screens, but subjects were able to return to the picture screen at will before the experiment started. The remaining third of the subjects received the set of actual components (Figure 3.1c) placed at eye-level aside the computer during the instructions. The set was removed before the experiment started. Subjects could study the components and memorize their names without time limit, since only the latter were presented during the experiment.

Subjects were told that each time a triplet of component names was auditoearly presented, they had to combine these three components into a creative object (for comparable instructions, see Tarrant, 1993). They were allowed to vary size, position, and orientation of each component and were free to determine the materials (e.g. wood, plastic) of the components. They were not allowed, however, to bend or otherwise alter the components (conform to the instructions in Finke and Slayton, 1988, and Anderson and Helstrup, 1993a&b). At the end of the instructions an example of a creative product drawn from the collection of Finke (1989) was shown as an illustration.

A trial started with an auditory presentation of a triplet of component names. The names were presented in random order. Each subject was given a 2 minutes time interval to create an object from these components. One half of the subjects were to sketch during the 2 minute interval: the with-sketch condition. The other half was not allowed to sketch, and performed the task with their eyes closed: the without-sketch condition. To control for gender differences on imagery tasks (see for example Forisha, 1981), the with-sketch and without-sketch conditions contained equal numbers of male and female subjects.

All subjects had to wait for the end of the 2 minute interval, which was marked by an auditory signal. On a fresh sheet of paper, they wrote down the name and description of their object. Next they drew the object on another sheet of paper. They were not allowed to alter their description after having started drawing. Subjects completed both description and drawing without time constraint. All subjects thus received the 8 predetermined triplets in a random order. The experiment lasted on average about 45 minutes, although considerable differences between subjects were noted.

Following the lead of Finke and Slayton (1988) and Anderson and Helstrup (1993a&b) all subjects received an exit checklist. They indicated retrospectively, which one of the following options applied most to their activities: (1) combining the components by trial and error until a recognizable pattern occurred in the image or drawing; (2) thinking of a pattern and then try to manipulate the components mentally or physically so as to create it; (3) not using imagery or drawing at all, but thinking about how to combine the parts; and (4) using some other strategy.
The checklist was followed by two tests, administered in random order: a paper-folding (punched holes) test lasting 6 minutes (Ekstrom, French, & Harman, 1963), measuring visualisation ability, and Kunzendorf's aesthetic preference test (Kunzendorf, 1982), measuring creativity.

After completion of these tests the subjects evaluated their own objects. They rated each one on three 5-point scales. The first scale represented the originality of the object, ranging from 1 (absence of originality) to 5 (very original). The second scale represented the creativity of the object ranging from 1 (absence of creativity) to 5 (very creative). The third scale represented the practicality, ranging from 1 (absence of practicality) to 5 (very practical).

**Scoring.** Each object was re-drawn using a computer drawing program. This technique, which was applied blindly with respect to the conditions, standardized the straightness of the lines, precision of the edges and corrected the perspective if needed. This technique was applied to prevent that drawing accuracy should influence creativity ratings. 5 Independent judges were instructed to rate the re-drawn objects on creativity, originality, and practicality, the same scales as were used by the subjects for their evaluation. All judges were associates of the Faculty of Industrial Design Engineering, and were blind with respect to the conditions.

To measure the difference in analytic or synthetic processing between the with-sketch and without-sketch conditions, the object drawings were scored on traces of analytic and synthetic processes. For this purpose, two procedures were developed to measure synthesis and analysis. Both the analytic and the synthetic measure were calculated for an individual subject as a summed score across all eight trials.

To obtain the measure of synthesis, spatial configurations were classified, according to whether a component was inside or outside another component, and whether the components were aligned horizontally, vertically or diagonally. Figure 3.2 shows the 38 categories that could thus be formed. Figure 3.3 illustrates some of these categories with an object from the experiment. The synthetic measure equals the number of different categories that a subject used across trials. The measure thus reflects the variety across the eight objects in the way components were assembled in a spatial configuration. It was assumed that this variety reflects the richness of divergent production (Guilford, 1967) in synthetic processing. As the subjects had to conceive 8 objects, the highest score that could be obtained on synthesis is 8.
### Figure 3.2.

38 Synthesis categories, 32 presented in frontal view, 4 in planar view and 2 rest categories. Each of the three components of an object is represented by a circle. Overlapping circles symbolize the occurrence of one component containing the centre of another. A component is categorised as being outside an other component, if its centre lies on the edge or outside an other component, illustrated in the table by connecting circles. Rotation of objects along their vertical axis was performed (if necessary) in order for an object to fall into one of the categories. The categories N and O, denoting respectively the category where the three components were not connected and the category where an extra component was added or one component was missing, are the only two categories in which the exact location of the components was not taken into account.
Figure 3.3. Examples of some of the synthesis categories as listed in Figure 3.2. Objects in the categories A1, A2, A3, B1, D1, F1, F2, G3, H and I are made by the without-sketch group, the remaining objects by the with-sketch group.
To obtain the measure of analysis, each individual object was scored for presence (1) or absence (0) of a set of 6 preconceived criteria. Each of these criteria reveals that the structure of the original components has been changed and could therefore be called analytic features: size difference between the components (one or two components smaller or larger than the third, max. score = 1), embedding (of a component in one or two other components, max. score = 2), modification (a component becomes a total different form, max. score = 3), subtraction (whether the object contains one or two as voids in another component, max. score = 2), complexity of junctions (whether the penetration line at the junction between two components has a shape other than a circle or square, max. score = 2) and proportions (whether one of the components has proportions more than a factor 2 different from the instructions, max. score = 3). Figure 3.4 illustrates each analytic feature with an example taken from our result section. Two of the analytic features from this measure, size difference and embedding, formed also part of Anderson and Helstrup's (1993a&b) collective measure of transformational complexity. Two analytic features, proportion and modification, were discouraged by the instruction. A considerable amount of them was expected to occur nevertheless, if analysis is an essential part of the creative process.

Scores on each criterion were summed for each object. Thus, the maximal score for an object is 13. The analytic measure for a subject is the sum of all the scores for all objects. Because 8 objects were to be created, the maximal score of an individual subject is $8 \times 13 = 104$. 
Figure 3.4. Examples of each analytic aspect. In the first object the diamond is embedded in the cube, no other analytic features apply to this object hence it’s analytic score is 1. The cylinder of the second object is a negative (hollow) form, furthermore it is embedded in the cube, the sphere is about half the size of the cube, the resulting score for this object is 3. In the third object the cylinder has changed proportions and the cone is half the size of the flat square, hence the score equals 2. Both the cone and the sphere are embedded in the fourth object and less than half the size of the cube, this yields a score of 3. A complex junction occurs in the fifth object when the sphere penetrates the diamond, the flat square is embedded in the diamond; an analytic score of 2. In the last object the sphere is halved, furthermore the flat square is embedded in the modified sphere, an analytic score of 2 applies.
Results and Discussion

Initial description. 235 Objects (5 failures) were created in the without-sketch condition, vs. 229 objects (11 failures) in the with-sketch condition, a non-significant difference. Many subjects complained about the complexity of the diamond. It turned out that 14 of the 16 failures occurred with a diamond as component. Component complexity is therefore a potentially relevant factor in scoring creativity or processing. However, on our measures (analysis, synthesis and creativity ratings) the pattern of results for objects containing the diamond is similar with respect to sketching effects. Component complexity will therefore be discarded.

The independence on component complexity did not hold for the creativity criterion used by Finke and Slayton (1988) and Anderson and Helstrup (1993a&b). In order to compare our results to their earlier studies, one analysis was performed in which we adopted their criterion of creativity: objects were scored only if they received a rating of at least 4 on creativity by two of the three expert judges. (See the “ratings” section for how these judges were selected.) The diamond was not used in these earlier studies. Therefore a separate analysis was made for objects with (4) and without (4) the diamond. For objects with the diamond, equal numbers of objects were scored as creative in the with-sketch condition and the without-sketch condition (3 vs. 5; \(\chi^2(1)=.431\) p = .512). For objects without the diamond, a significant larger number scored as creative in the with-sketch condition than in the without-sketch condition (14 vs. 5; \(\chi^2(1)= 4.692\) p = .030). No differences were found for scores of originality or practicality.

The effect obtained for creativity for objects without the diamond differs from the null result obtained by Anderson and Helstrup (1993a&b). In accordance with the hypothesis (see also Verstijen et al., submitted-a), this result could be attributed to the fact that expert sketchers were used as subjects in the present experiment. The differential effect of component complexity suggests that sketching effects on Finke’s and Slayton’s creativity criterion are related to a reduction in process load or working memory capacity.

In the exit checklist, 21 subjects (70 %) in the without-sketch condition checked option 1: combining the components by trial and error until a recognizable pattern occurred in the image. Finke and Slayton (1988) obtained a comparable percentage (74.4%). The number of subjects who checked this option in the with-sketch condition is 15 (50%), which is significantly lower (\(\chi^2(1)= 4.712\) p = .0299). For this reason, a measure independent on load is probably more useful for comparison across conditions.

The subjects’ overall ratings of their own objects showed no significant difference between the without-sketch and with-sketch conditions. Female subjects did not rate themselves different from male subjects. Self-ratings confirmed that the diamond was considered a difficult component: trials with a diamond scored significantly higher on creativity (F(1,461)= 9.070; p = .0027), but trials without a diamond scored significantly higher on practicality (F(1,461)= 12.942; p = .0004).
Ratings. High agreement was obtained among three of the five independent judges (initials R., A., and K.) on all the rating scales, according to IntraClass Correlation (ICC, Shrout & Fleiss, 1979). On creativity: ICC(2,1)= .24, F(463,926)= 1.965; p << 0.01; on originality: ICC(2,1)=.22, F(463,926)= 1.23; p << 0.01; and on practicality: ICC(2,1)= .27, F(463,926)= 2.44; p << 0.01. R., A. and K. are Industrial Design Engineering teachers. The remaining two judges were not industrial design professionals. Their ratings showed zero agreement with each other (their IntraClass correlations on creativity, originality and practicality show insignificant values of respectively -0.06, 0.04, and -0.02), and caused a considerable drop of ICC values if combined with R., A. and K. For these reasons, the ratings of the last two judges were not used. In contrast to the reported ‘treasure hunt’ by Finke’s judges, all judges considered their task boring, although they had to rate only one fifth of the amount of objects used in Finke’s experiment (Finke, 1990, p. 43).

Each created object received the sum of the ratings by R., A. and K. Subjects received the summed ratings of all their objects. This procedure takes into account that some subjects did not succeed in creating the maximal number of 8 objects.

The factors Sketch (with-sketch/without-sketch), mode of Presentation of the components (wire frame/flat-shaded/actual) and Gender (m/f) resulted in a 2*3*2 factorial design, with the judges’ ratings as dependent variable and subjects as random factor: each resulting block contained 5 subjects. A three-way factorial ANOVA (Sketch * Presentation * Gender) performed on creativity, originality and practicality indicated no significant effects (neither main effects nor interactions) on any of these ratings.

That objects made by sketching receive equal creativity ratings, compared to those in imagery conditions, is not in line with the predicted effect of sketching. Yet, it can be argued that, when creativity ratings are differentiated with the aid of the analytic measure (these results will be discussed at more length later), a dependency is revealed. Figure 3.5 plots the mean creativity ratings for the with-sketch and without-sketch condition, against the number of analytic features per subject. Figure 3.5 shows that as compared to the without-sketch condition, the with-sketch condition received much lower creativity ratings if they applied few analytic features but their ratings increased faster when more analytic features were applied. Although judging was done by a blind procedure, the judges, who are domain experts, have criteria to distinguish the conditions. As a result, they seem to attribute more praise for the use of analytic strategies in the with-sketch conditions than in the without-sketch condition, and more blame for omitting them. This result forms a motivation to differentiate between synthetic and analytic processing.
Figure 3.5. Mean creativity ratings on total analysis score, split up for the with-sketch and the without-sketch group.

**Synthetic Measure.** Table 3.1 shows how the objects created are distributed over the synthesis categories of Figure 3.2. In only 1 out of 38 possible cases, a difference between the without-sketch and the with-sketch condition reached significance at .05 level, in accordance with chance-level expectations. Type of object structure, therefore, fails to distinguish between the conditions.

All subjects used more than one synthesis category across the eight trials. The minimum number was 2 and the maximum was 8. This number constitutes a subject's *synthesis score*. A three-factor ANOVA was performed on the synthesis scores, with Sketch (with-sketch/without-sketch), mode of Presentation of the components (wire frame/flat-shaded/actual) and Gender (m/f) as factors. For sketching the mean synthesis score in the without-sketch condition (m= 5.367, Std.Err= .176) equals that of the with-sketch condition (m= 5.4, Std.Err= .252) (F(1,48)= .012; p= .914). For Gender, male subjects (m= 5.767; Std.Err= .196) scored significantly higher than female subjects (m= 5; Std.Err= .214; F(1,48)= 6.97; p= .011). No other effects reached significance. The absence of a sketching effect is in accordance with the hypothesis that synthesis doesn't benefit from sketching, provided the measure is valid.
An argument for the validity of the synthesis measure could be obtained from its correlations with the creativity ratings (see Table 3.3). Synthesis scores correlate significantly with creativity ratings in both sketching conditions (for the without-sketch condition: \( r = .482; T(28) = 2.911; p < .01 \), for the with-sketch condition \( r = .581; T(28) = 3.777; p < .01 \). No correlation with other ratings or tests were obtained, except with originality in the without-sketch condition (\( r = .477; T(28) = 2.872; p < .01 \)).

<table>
<thead>
<tr>
<th>Synthesis category</th>
<th>without-sketch</th>
<th>with-sketch</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>35</td>
<td>28</td>
</tr>
<tr>
<td>A2</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>A3</td>
<td>10</td>
<td>18</td>
</tr>
<tr>
<td>A4</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>A5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>B1</td>
<td>17</td>
<td>6</td>
</tr>
<tr>
<td>B2</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>B3</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>B4</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>B5</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>C1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>C2</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>C3</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>C4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>D1</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>D2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>D3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>D4</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Synthesis category</th>
<th>without-sketch</th>
<th>with-sketch</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>E2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>E4</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>F1</td>
<td>68</td>
<td>75</td>
</tr>
<tr>
<td>F2</td>
<td>11</td>
<td>14</td>
</tr>
<tr>
<td>F3</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>G1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>G2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>G3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>H1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>H2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>I</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>J</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>K</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>L</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>N</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 3.1. Synthesis categories from Figure 3.2 with their corresponding occurrences in objects made by expert sketchers in the without- and with-sketch groups. No objects appeared in the categories E3, M, and O.

**Analytic Measure.** A three-factor ANOVA was performed, with Gender (m/f), mode of Presentation of the components (wire frame/flat-shaded/actual) and sketching (with-sketch/without-sketch) as factors and subjects' analytic measure scores as dependent variable. The with-sketch condition (\( m = 15.333; \text{Std.Err.} = .956 \)) scored significantly higher than the without-sketch condition (\( m = 11.97; \text{Std.Err.} = .648 \)) (\( F(1,48) = 8.382; p < .01 \)). No other effects approached significance. No interactions occurred. The effect of sketching is in accordance with the prediction. Significant differences could also be established for three of the constituents of the analytic measure separately: embedding, size differences and proportions. Table 3.2 gives the mean scoring for each analytic feature.
Interestingly, the number of complex junctions-in-sight differed significantly between the with-sketch and without-sketch conditions ($F(1,48) = 6.113$; $p = .017$). Subjects in the without-sketch condition hid most of the complex junctions at the backside of their objects, while subjects in the with-sketch condition were more likely to put them into sight. This result illustrates the flexibility of subjects in dealing with the constraints of imagery. In the discussion of the creativity ratings, it was observed that expert judges were able to distinguish between with-sketch and without-sketch conditions, even though judging was done by a blind procedure. Whether complex junctions were in or out of sight may have been one of their criteria.

<table>
<thead>
<tr>
<th>Analytic Measure</th>
<th>with-sketch</th>
<th>without-sketch</th>
<th>ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size difference</td>
<td>3.9 (.308)</td>
<td>&gt;&gt; 2.8 (.277)</td>
<td>$F(1,48) = 6.153$; $p = .017$</td>
</tr>
<tr>
<td>Proportions</td>
<td>3.3 (.24)</td>
<td>&gt;&gt; 2.367 (.367)</td>
<td>$F(1,48) = 4.193$; $p = .046$</td>
</tr>
<tr>
<td>Embedding</td>
<td>2.324 (.424)</td>
<td>&gt;&gt; 1.406 (.257)</td>
<td>$F(1,48) = 4.084$; $p = .049$</td>
</tr>
<tr>
<td>Complex junction</td>
<td>1.402 (.256)</td>
<td>&gt; 1.129 (.206)</td>
<td>$F(1,48) = 3.447$; $p = .069$</td>
</tr>
<tr>
<td>Modified</td>
<td>1.033 (.223)</td>
<td>= .767 (.223)</td>
<td>$F(1,48) = .559$; $p = .458$</td>
</tr>
<tr>
<td>Negative</td>
<td>.8 (.211)</td>
<td>= 1.233 (.238)</td>
<td>$F(1,48) = 1.788$; $p = .187$</td>
</tr>
</tbody>
</table>

**Table 3.2.** An overview of the analytic aspects as illustrated in Figure 3.4. The first column lists the different properties. The second column concerns the mean number of occurrences found in the objects created in the with-sketch versus the number in the without-sketch group in the fourth column, the fifth column lists the ANOVAS on the factor Sketch. The other two factors, Gender and Presentation, revealed no significant differences on any of the analytic aspects.

Analysis scores correlated significantly with creativity ratings in the with-sketch condition only (for the with-sketch condition, $r = .613, T(28)= 4.106; p<.01$; for the without-sketch condition, $r = .141$). The difference between these correlations is significant ($Z = 2.102; p<.05$). Analysis scores correlated significantly with originality ratings for the with-sketch condition only (for the with-sketch condition, $r = .412, T(28)= 2.393; p<.05$, for the without-sketch condition, $r = .092$). No significant correlation was found with practicality judgements (for the with-sketch condition, $r = -.253$ and for the without-sketch condition, $r = -.022$). None of the correlations of the analysis measure and test scores were significant.
**Correlations between dependent variables.**  Table 3.3 lists the correlations obtained between synthesis scores, analysis scores, ratings of creativity, originality, and practicality. A significant correlation between synthesis and analysis scores existed only for the with-sketch condition (for with-sketch conditions, $r = .420, T(28) = 2.449, p < .05$; for the without-sketch condition, $r = .225, T(28) = 1.222, p > .05$). This result raises the question, whether analysis and synthesis contribute independently or jointly to creativity. Partial correlation between synthesis and analysis with creativity ratings partialled out, reduces it from .420 to a near-zero value (.099) for the with-sketch group and only from .225 to .181 in the without-sketch group. This could indicate that in the sketching condition, analysis and synthesis processes contribute jointly to the a creative object.

<table>
<thead>
<tr>
<th>Without-sketch</th>
<th>A</th>
<th>S</th>
<th>C</th>
<th>O</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>.225</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>.141</td>
<td>.482**</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>O</td>
<td>.092</td>
<td>.477**</td>
<td>.826**</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>-.023</td>
<td>-.343*</td>
<td>-.347*</td>
<td>-.303</td>
<td>1.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>With-sketch</th>
<th>A</th>
<th>S</th>
<th>C</th>
<th>O</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>.420*</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>.613**</td>
<td>.581**</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>O</td>
<td>.413*</td>
<td>.294</td>
<td>.766**</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>-.253</td>
<td>.166</td>
<td>-.223</td>
<td>-.258</td>
<td>1.00</td>
</tr>
</tbody>
</table>

**Table 3.3.**  Correlation matrices for the without-sketch and the with-sketch groups of $A$ (Analytic measure), $S$ (Synthetic measure), $C$ (Creativity rating), $O$ (Originality rating) and $P$ (Practicality rating). Shaded areas indicate significant difference in correlation between the two groups.
Experiment 2

Method

Subjects. Twenty-three subjects (13 female and 10 male) took part in the experiment. All were novice sketchers, recruited from first year undergraduate psychology students. All received course credit for participation. Their mean age was 19.7 years, ranging from 17 to 39. 6 Female and 5 male subjects participated in the with-sketch condition; 7 female and 5 male, participated in the without-sketch condition.

Apparatus, Stimuli, Procedure and Scoring. Identical to Experiment 1, except that the created objects were not rated on creativity, originality and practicality.

Results and Discussion

Initial description. A total of 168 objects was created, not significantly less in the with-sketch condition (81) than in the without-sketch condition (87). 12 Of the 16 trials where subjects failed to complete an object contained the diamond. The difficulty of the diamond is in accordance with Experiment 1.

Synthetic Measure. Table 3.4 shows how the objects created are distributed over the synthesis categories of Figure 3.2. In only 1 out of 38 possible cases, a difference between the without-sketch and the with-sketch condition reached significance at .05 level, in accordance with chance-level expectations. This result confirms that type of object structure fails to distinguish between the conditions.

A three-factor ANOVA was performed on the synthesis scores, with Sketch (with-sketch/without-sketch), mode of Presentation of the components (wire frame/flat-shaded/actual) and Gender (m/f) as factors. In accordance with the hypothesis that synthesis doesn't benefit from sketching, for Sketch the mean synthesis score in the without-sketch condition (m= 4.583, Std.Err.= .499) equals that of the with-sketch condition (m= 4.909, Std.Err.= .530) (F(1,11) = .42; p= .531). Neither did any of the other effects reached significance.
Table 3.4. Synthesis categories from Figure 3.2, with their corresponding occurrences in objects in the without- and with sketch group of novices. No objects appeared in the categories A4, A5, B5, C1, C2, C4, E2, K and L.

Analytic Measure. A three-factor ANOVA was performed on the analysis scores, with Sketch (with-sketch/without-sketch), mode of Presentation of the components (wire frame/flat-shaded/actual) and Gender (m/f) as factors. For sketching the analysis scores in the without-sketch condition (m=10.08, Std.Err.=1.665) equals those of the with-sketch condition (m=8.09, Std.Err.=.848) (F(1,11)=.565; p=.468). None of the effects reached significance. Neither could significant values be established for each analytic feature separately either. The absence of a sketching effect is in accordance with the findings of Anderson and Helstrup (1993a&b) and Verstijnen et al. (submitted-a) that novices don’t benefit from sketching.

Correlations. No significant correlations were obtained between synthetic and analytic measures, nor with any of the test scores.

Experts vs. Novices. Because the mean number of objects constructed by novices (m=7.304) was significantly lower than that of the experts in Experiment 1 (m=7.733, T(81)=2.093; p<.05), we have to correct for this difference in number of objects in order to compare novices (Experiment 2) and experts (Experiment 1). This was done by dividing each subjects’ synthesis and analysis score through the number of objects created by that subject, resulting in a Corrected Synthesis score and a Corrected Analysis score.
Two-factor ANOVAS were performed on the Corrected Synthesis and Analysis scores, with Expertise (novices/experts) and Sketching (with-sketch/without-sketch) as factors. The corrected synthesis score of experts (m= .696, Std.Err.: .046) was equal to that of novices (m= .651, Std.Err.: .019) (F(1,79)= 1.088; p= .3001). No effect could be established for Sketching, no interaction effects were obtained. It can be concluded that synthesis is not influenced by expertise.

The corrected analysis score of experts (m= 1.767, Std.Err.: .078) was significantly higher than that of novices (m= 1.272, Std.Err.: .127) (F(1,79)= 13.046; p< .001). The interaction between expertise and sketching was significant; the mean corrected score in the with-sketch groups was for experts m= 2.001 (Std.Err.: .118) and for novices m= 1.065 (Std.Err.: .202), in the without-sketch groups these scores were respectively m= 1.531 (Std.Err.: .083) and m= 1.462 (Std.Err.: .143) (F(1,79)= 9.703; p < .001). It can be concluded that analysis increases with sketching for experts, but no such relation was obtained for novices. See Figure 3.6.

![Figure 3.6](Note: The figure is not a hyperlink in the text, but it is mentioned that it shows the mean analysis scores in without- and with-sketch groups of expert sketchers and novices. For experts the difference between with- and without-sketching is significant, for novices it is not.)
With respect to the distribution of objects over the 38 synthesis categories, in 2 out of 38 cases a significant difference between novices and experts was obtained. This result is in accordance with chance-level expectations, from which it can be concluded that experts and novices do not differ in preference for a specific synthesis category.

In comparison with the experts of Experiment 1, the novices of the present experiment scored significantly higher on Kunzendorf’s aesthetic preference test (novices: m = 8.435, Std.Err.: .506; experts: m = 11.217, Std.Err.: .337; T(81) = 4.427; p < .001; the test uses an inverse scale), but significantly lower on the Ekstrom et al. (1976) paper-folding test (novices: m = 14.478, Std.Err.: .829; experts: m = 17.017, Std.Err.: .351; T(81) = 3.33; p < .001). None of these tests correlated significantly with product ratings in Experiment 1. For Kunzendorf’s aesthetic preference test, this result was in accordance with Verstijnen et al. (submitted—a), where this test provided a reliable indication of individual creativity only in spontaneous sketching conditions, but not in compelled sketching conditions. This, in combination with the fact that the pattern of the test scores is inconsistent, makes it unlikely that individual creativity differences between experts and novices are responsible for effects of sketching.
Experiment 3

In the introduction it was suggested that Anderson and Helstrup's (1993a&b) transformational complexity measure remained insensitive to sketching effects because it results from a summation of analytic and synthetic measures. In Experiment 3 the transformational complexity measure was applied to objects obtained with the original Finke paradigm, to see whether this measure indeed smoothes away the effects of sketching. Two constituents of this measure (mirror imaging and rotation) could be considered synthetic and two (size and embedding) analytic features. Therefore the individual constituents of transformational complexity were considered separately, to test if these differentiate between the sketching conditions for experts.

Method.

Subjects. Seventeen subjects (8 female and 9 male) took part in this experiment. Mean age was 23.2 years, ranging from 21 to 27 years. All were expert sketchers by the same requirements as in Experiment 1. None of them participated in Experiment 1. All received financial reward for their participation.

Apparatus and Stimuli. Apparatus was identical to that of Experiment 1. The total set of 15 components used was adopted from Finke and Slayton (1988). All components had similar sizes. Ten simple components (circle, square, triangle, rectangle, horizontal and vertical line and the capital letters, D, L, T and C) and five complex ones (capital letters J, X, V and P and number 8) were distinguished.

Procedure. The subjects subscribed to the experiment listed as "Playing with Figures". Subjects were instructed the same way as in Experiments 1 and 2. 10 Subjects (5 male and 5 female) took part in the with-sketch condition, 7 (4 male and 3 female) in the without-sketch condition. Order of events within a trial also matched Experiments 1 and 2. Each subject received 10 trials. As compared to Experiment 1 and 2, the new element in the procedure was, in accordance with Finke and Slayton (1988), that random components were selected for each trial. These were drawn with a .75 probability from the simple and with a .25 probability from the complex components. No pre- or post tests were taken.
Scoring. Anderson and Helstrup's (1993a&b) transformational complexity measure of an object was determined by counting the number of transformations of each component needed to create an object. Following the lead of the authors, the transformation score equals the sum of scores on Size, Rotation, Mirror Imaging and Embedding. An object scored 0 on Size if all three component had equal sizes, 1 if two components had similar sizes and the third was larger or smaller, 2 if all three components had different sizes. A score of 1 for each component in an object was obtained on rotation if the object contained a component rotated 90º or 180º from normal (i.e. the presentation orientation). Components with rotations somewhere in-between got a rotation score of 2. Each mirror imaged letter J or P scored 1. When a component was embedded in another component this yielded an Embedded score of 1, when two components were embedded in the third component but not in each other; this scored 2, and finally all three components embedded in each other yielded a score of 3. (Anderson, personal communication). The transformational complexity score adds up to a maximum of 13.

Results

An object was produced on every trial, resulting in a total of 170 objects. The mean transformational complexity score was m = 2.88 (Std.Err.: .181) for the with-sketch condition and m = 3.227 (Std.Err.: .241) for the without-sketch condition. As in Anderson and Helstrup (1993a&b), the difference was not significant (F(1,168) = 1.385; p = .241). However, when we split up the transformational complexity score in its constituents (see Figure 3.7), Orientation and Mirror Imaging scored significantly lower in the with-sketch condition than the without-sketch condition. (For Orientation, respectively m = 1.62; Std.Err. = .146 versus m = 2.157; Std.Err. = .208; F(1,168) = 4.743; p = .031, and for Mirror Imaging respectively m = .02; Std.Err. = .014 versus m = .086; Std.Err. = .034; F(1,15) = 4.012; p = .047). These constituents of the transformational complexity measure could be identified as synthesis measures.

A different effect was obtained for the remaining constituents of the score. Size yields a significant higher mean score in the with-sketch than in the without-sketch condition (m = .82; Std.Err. = .061 vs. m = .557; Std.Err. = .072; F(1,168) = 7.705; p = .006). Equal scores were obtained for Embedding in the with and without-sketch conditions (m = .420; Std.Err. = .067 vs. m = .428; Std.Err. = .085; F(1,168) = .006; p = .936). The lack of effect for this last measure could be ascribed to the fact that embedding only creates overlap and hence the 2D components are not restructured by embedding, in contrast with the 3D figures of Experiment 1-2. Hence, only the constituent of transformational complexity called Size could be identified as an analytic measure in the context of the present experiment. The absence of effect in the overall, transformational complexity score as used by Anderson and Helstrup (1993a&b) could therefore be ascribed to the opposite tendencies in the synthetic and analytic constituents of this measure.
Figure 3.7. The mean scoring on the four constituents of Anderson and Helstrup’s Transformational Complexity score, split up for the with- and without sketch groups. On the analytic aspect Size of this score the with-sketch groups score considerably higher than the without-sketch group, the opposite distribution is found on the synthetic constituents Mirror Image and Rotation.
General Discussion

Three experiments provided evidence for a distinction between synthetic and analytic processing in the figural combination task. Measures of analytic processing scored differently from those of synthetic processing with expert sketchers. Analytic processing was increased by sketching. In contrast, measures of synthetic processing were found indifferent to sketch conditions and expertise.

The results support the conclusion that whereas synthesis is easy and can be performed in imagery by novices and experts equally well, performing analysis is difficult in imagery and requires support of sketching. Sketching provides subjects with an externalized visual presentation of their image. That analysis is facilitated by visual presentation conditions, is in accordance with the fact that ambiguous figure reversals spontaneously occur in perception, but are difficult to obtain in imagery conditions (Chambers & Reisberg, 1985).

Only experts could benefit from sketching facilities. On the basis of test scores, it is unlikely that this effect can be ascribed to a greater individual creativity in the expert sketchers (see also Verstijnen et al., submitted-a); without sketching, both groups performed equally. Moreover, if any pattern could have been expected on account of the test scores, it would have been a larger effect for novices. For this reason, the propensity of experts to benefit from sketching can only be explained on the basis of their drawing skills.

A possible explanation based on drawing skills is, that novices attribute more attention to the sketching and are therefore distracted from the imagery process. However, the same effect of expertise was obtained by Verstijnen et al. (submitted-a), where the drawings were much simpler and unrestricted time was given to complete them. Therefore, in accordance with the earlier suggestion, the more likely explanation is that expert sketchers create an accurate visual presentation. With this, experts can successfully perform analysis. That the accuracy of sketching seems to be the crucial issue is suggested by the fact that in Verstijnen et al. (submitted-a) judges could reliably distinguish novice and expert sketches.

In the present experiments, judges differed in appraisal for analytic processing, depending on whether sketching was allowed. This effect is interesting in itself, because the judging was done blindly with respect to conditions. The objects produced must therefore reflect the circumstances of their creation. That experienced judges (design teachers) are sensitive to these conditions, may not come as a surprise. Possibly, they were able to distinguish between analytic features, accidentally produced in the without-sketch condition and those intentionally produced in the with-sketch condition. An argument for the intentional character of the analytic processing is suggested by the correlation between the analytic measure and the creativity ratings. This correlation was restricted to the sketching subjects. One criterion, by which judges could have distinguished sketch from non-sketch conditions, consists in the
presence or absence of a complex junction-in-sight. In sketch-conditions, most complex junctions between components were in sight, in non-sketch conditions they were on the backside. This illustrates that for the study of creativity, it could be useful to distinguish synthesis and analysis measures.

The distinction proved useful for interpreting the transformational complexity measure used by Anderson and Helstrup (1993a&b). This measure was shown to consist of a summation of both synthetic and analytic constituents of the task. Its analytic constituent Size Difference scored higher in the with-sketch condition than in the without-sketch condition and this effect was counter balanced by an opposite effect on the synthetic constituents Orientation and Mirror Imaging. As a result, the sum scored measure indicates equal complexity for sketch and non-sketch conditions, in spite of the differential contributions of analytic and synthetic processing.

Finke (1990) used the term "combinational play" to indicate the transformations by which components in his task are combined. The term "play" suggests a haphazard character of the search for innovative ideas, rather than a goal-oriented strategy. In accordance, the majority of subjects investigated reported trial-and-error strategies. This was more strongly the case in the without-sketch condition. In this condition, synthesis prevails over analysis, as the comparison of experts and novices in Figure 3.6 suggests. Given the haphazard character of combinational play, a measure that is relatively independent on process load is required. Anderson and Helstrup (1993a&b), following Finke and Slayton (1988), only considered highly creative objects. In our experiments, this measure was shown to be strongly dependent on processing load. Resource limitations could have therefore been responsible for the absence of effects in their experiments, in particular because novice sketchers had been used. In our ratings of experts, summed scores for all objects computed showed the required independence of processing load.

The present study shows that there are both similarities as well as dissimilarities between perception and imagery (Kosslyn, 1980; Finke, 1985). The similarity presently emphasized is that the functional distinction between analytic and synthetic processing strategies applies both to perception and imagery. The greater liability to analysis distinguishes imagery from perception, allowing this difference to be a matter of degree.

That even within imagery, the possibility of analysis is a matter of degree, is suggested by a contrast between Verstijnen et al. (submitted-a) and the present experiments. In Verstijnen et al. (submitted-a), no analysis at all was performed by the non-sketching group; the present experiments show less, but still a considerable amount of analytic processing. Although the analytic measure used is blind to accidental or intentional use of analytic processing, the fact that this measure correlates with some of the ratings and test scores, suggests, that not all analytic processing scores are accidental. In Verstijnen et al. (submitted-a), analysis would have affected the part-whole relationship of the entire figure, whereas in the present experiments, it had impact only on the components and their local junctions.

For both experts and novices, a relation between subjects' synthesis score and the judged creativity of their products could be found. The synthesis score measures the variety in the combinatorial strategies a subject uses in creating an object. Comparable notions can
be found for example in the literature on divergent thinking related to creativity (e.g. Duncker, 1945; Guilford, 1967).

Combinational play as identified by Finke (1993) might be taken to coincide with a synthetic processing strategy. This would suggest that synthesis alone is responsible for creativity. In our view, however, creative products may result from synthetic and analytic processing. Synthetic processes, however, may be predominant in the current task. Analytic processing resources will be brought to contribute if circumstances allow this. In the sketching group, analytic strategies therefore contributed to the creativity scores of the end-products. When sketching is used, analytic and synthetic processes seem to co-operate to reach an optimal end-product. Analytic strategies may be intentional and therefore more dependent on motivation. Apart from creativity as a personal characteristic, intrinsic motivation has been suggested as a factor contributing to the creative product (Hennessey & Amabile, 1988). It may be concluded from our findings, that creativity has to do with the ability and willingness of people to combat the boundaries of imagery by choosing a medium (like paper and pencil). This choice can lead to success, only if combined with the possession of expertise in the medium and the willingness to fully exploit its possibilities.

Finke (1990) assumes that after combinatorial play has generated a new object, inspection is required. Inspection is a strategy to evaluate a generated object on desirable, useful or creative properties. The strict separation between combinatorial play and inspection suggests that the combination itself is performed blindly, i.e. without inspection. The fact that imagery and perception use the same resources, could be taken to suggest that performing transformations in imagery is not done blindly, but rather that our visual awareness continuously monitors the transformations (Shepard & Metzler, 1971). This would suggest that recognition of the creative object coincides with its generation, and that therefore, a separate recognition stage is not needed in order to account for the selection of an innovative product. Discovery by imagery alone, then, differs only in degree from discovery in perception. Both are active processes, involving analytic and synthetic strategies, perception being more inclined to analysis and imagery more to synthesis. The reason would be that the components of imagery are obtained as wholes from memory.
CHAPTER 4

Sketching in Practice

Abstract

The aesthetic experience of a work of art occurs usually only after prolonged viewing, which allows hidden regularities, or surplus structure, to be revealed. Studies in experimental aesthetics suggest that surplus structure is maximally effective if a tension could be created between a predominant interpretation and an independent other one, which coexists in a pattern. One of two coexisting interpretations will usually emphasize integral aspects of the pattern (global structure) and the other the set of its separate elements (local structure). A series of sketches by an abstract artist is examined to illustrate these phenomena. In trying to create tension between coexisting local and global interpretations, the artist manipulates structure in an iterative process, involving imagery, sketching, and perceptual processing of the sketch. In individual sketches, the artist attempts to combine local and global perceptual structure; across a series of sketches the time course in processing of local and global structure was observed.
Introduction and Overview

The creation of a piece of (abstract) art shares at least one important characteristic with the aesthetic appreciation of the product; both require the active inception of structure. Structural properties of art, such as balance, order, complexity, and incongruity have often been regarded as static stimulus properties. Backed up by Picasso’s famous dictum: “I don’t search, I find...”, this notion may be particularly misleading in the context of art making, because it conveys the belief that the right combination of structural properties is a matter of instantaneous detection in imagery, and all the artist has to do is to paint out his imagination.

In an attempt to characterize such beliefs, Margaret Boden (1990) distinguished two types: inspirational beliefs, reflecting a Platonic notion of insight as the discovery of an eternal ideal (see also Rothenberg & Hausman, 1976), and romantic beliefs, stressing the uniqueness of artistic and scientific talents. Either of these may be true of an exceptional genius but usually, the creative process of an artist is painstaking and far from instantaneous and, in this respect, far from unique. Creative processes, both of designers and innovative scientists, evolve slowly (Ippolito & Tweeny, 1995). It may therefore be considered useful to choose a notion of artistic structure, which is not timeless, but specified in reference to the way the creative process evolves.

Such a dynamic notion may provide a faithful description of art making as an iterative process of imagining, sketching, and perceiving the result of the sketch. Since the artist continuously evaluates his/her work, the processes involved in making art need to be understood as drawing heavily on resources that are also involved in the aesthetic apprehension of a completed work of art. Experimental aesthetics and perceptual processing studies, as well as imagery research, may therefore provide converging views on the time course of abstract art making. Recent studies of imagery have clarified the role of sketching in creative processing (Anderson & Helstrup, 1993a; Verstijnen, van Leeuwen, Hamel, & Hennessey, submitted-a; Verstijnen, Goldschmidt, van Leeuwen, Hamel, & Hennessey, submitted-b). From the proposed point-of-view the study of sketches can provide a useful contribution to the description of artistic production as well.

One of the main goals of the artist is, to invoke aesthetic experience in his audience. This is no less the case, if the work is created for the perceptual pleasure of the artist himself. In abstract art, perceptual structure is one of the major determinants of this experience (Hekkert, 1995). The perceptual structure usually will not invoke aesthetic experience immediately. Aesthetic experience will occur after prolonged viewing, which allows the work to reveal its hidden regularities, or surplus structure.

As we will argue, studies in experimental aesthetics suggest that surplus structure is maximally effective if a tension is experienced between the elements structure (local structure) and the integral, relational aspects of the pattern (global structure). The task of the artist may therefore consist in the production of a pattern in which local and global structure coexist. To achieve this result, the artist may combine powerful overall regularities with
interesting, hidden detail (noticeable also in figurative art, see for example Jeroen Bosch; Bouleau, 1963). Or, he may present an unexpected solution in the way in which components are joined into a global whole (as in Maurits Cornelius Escher’s work).

The notions of local and global in the domain of perceptual structure, differ from those often used in the spatial information processing literature (e.g., Navon, 1977). The spatial notions of local and global are of little significance for distinguishing perceptual object structure (Pomerantz, 1983). For this reason, functional notions of local and global are adapted from Gestalt psychology. A radically holist tendency has been predominant in Gestalt psychology, in particular in the Berlin school (Köhler, Koffka, Wertheimer). Such a view makes it difficult to study the elements of a local structure in isolation. For that reason, a more moderately holist version of the Gestalt notions of local and global is adopted for our present purposes. With these notions, it will be possible to describe the hidden regularities, or surplus structure of a work of art as a tension between local and global structure. This allows a view on how an artist uses perception, imagery and sketching in the process of creating a work of art which contains surplus structure.

The presently proposed account of local and global structure (see Figure 4.1) dates back to the original notion of Gestalt qualities (von Ehrenfels, 1890). In this approach, global wholes are relational structures, which are primary qualities of perception. The components of the global structure are subject to strong coherence constraints from the whole. Nevertheless, they can, in principle, be attended separately. For this reason, a global structure is not just described at the level of the whole, but contains multiple levels of description, allowing also a level of description for the separate components. Local structures differ from global ones in having weak coherence constraints among the elements. For that reason, it is easy to attend them separately; local perceptual structure, therefore, facilitates piecemeal perception (Peterson & Hochberg, 1983).

**Figure 4.1.** The notions local and global according to von Ehrenfels. In a local structure the elements are separately perceived or show a loose binding, whereas in a global structure they are integrated as components.
The artist involved in creating surplus structure will manipulate structure in an iterative process, involving imagery, sketching and perceiving the result of the sketch. These processes will be said to have partly overlapping, partly complementary functions. Perception, imagery, and sketching all are involved in the creation of local and global perceptual structure. Imagery differs from perception in at least one important respect: *analytic* processes are difficult in imagery (Verstijen et al, submitted-a). These processes involve modification of existing component structure and the creation of new component structures. Analysis is much easier in perception than in imagery (Reed, 1974). By contrast, creative processes involving the combination of components into more global structure are easily performed in imagery (Finke & Slayton, 1988; Finke, 1990, 1993). These processes can be performed in perception and imagery equally well (Anderson & Helstrup, 1993ab).

The contrast between perception and imagery explains why sketching is needed. A tension between coexisting global and local structures has to be created. Imagery can supply the global structure, but cannot come up with an independent local representations for its components. Sketching will have to provide the additional local structure, required for surplus structure. The techniques used to create surplus structure could therefore be observed in sketches of an artist.

A series of sketches could be even more informative. Let us assume that newly formed structures are stored in episodic memory for later use during the creative process. During the creative process, a vocabulary of structures is accumulated, from which the artist can draw. According to our hypothesis on processing in imagery, its time course on episodic level will show a general characteristic: *creative* imagery will only involve the production of *global* structure. So with the time course of a process, the structures that are kept in episodic memory will, on average, become increasingly global.

A similar long-term tendency has been observed in perceptual processing as well. Goldstone and Medin (1994) observed this process in classification of complex patterns. Classification was originally on the basis of local isolated features, and later according to global structure. Van Leeuwen, Buffart, and van der Vegt (1988), observed the same phenomenon in serial pattern learning. All these visual processing experiments share the feature of global structure accumulation in episodic memory. This is expected to occur in imagery during a creative process of an artist as well. A series of sketches will reveal this episodic tendency.

We will argue that if sketching is further prolonged, the increase in global bias in imagery makes it increasingly difficult to supply the additional local structure through sketching. This may result in an inverted U-shaped function of the creativity of the sketches as a function of time. In the earliest sketches, local structure will be predominant; in the late ones it will no longer be possible to create surplus structure. The optimum will be somewhere in the middle of this process. If an optimal solution has not been reached, the final sketches will reveal a predominantly global perceptual structure, without surplus structure. The artist will decide to give up working on a series, in an attempt to make a fresh start.
All these phenomena will be illustrated in a series of sketches made in the process of creating a work of abstract art, a series of sketches made by the Dutch abstract painter Paul Kleijne. This session was, according to the artist's own views, a particularly uninspired one. In fact, we had considerable difficulty in convincing him to give this material free for publication; it is certainly not representative of the quality of his work. In the context of the present study such an uninspired session could still contribute to understanding the creative process. This artist focuses on specific techniques for creating surplus structure, using mosaic and occlusion interpretations of simple, geometrical shapes. Although other techniques for creating surplus are possible, our discussion will focus on the ones used by Paul Kleijne, whose work has played an important role in the construction of the presently proposed theory.

The next three sections will discuss recent developments in three different fields, which have led us to propose these views. These fields are, first, the study of aesthetic appraisal, second, perception of structure and, third, imagery and sketching. The first field contributes to the notion of surplus structure, the second will focus on the discussion of the time course in perception, and the third will discuss the creative processes in imagery. The combination of the information gathered in these fields will allow us to detail out the predictions on the time course of creative surplus structure in a subsequent paragraph, before we turn to the discussion of the series of sketches by Paul Kleijne.
Studies of Aesthetic Appraisal.

The artist produces his work, among others, in order to elicit aesthetic appraisal. Predominantly in abstract art, aesthetic appraisal of a painting or drawing will be elicited by its structural or organizational properties. Hekkert and van Wieringen (1990), for instance, demonstrated that beauty ratings of non-categorizable, i.e. abstract, cubist paintings were significantly related to complexity scores, whereas ratings of figurative paintings were not. In accordance with a prediction derived from Berlyne's (1971) psychobiological theory of aesthetics the relationship between beauty and complexity was of an inverted U-shape, indicating that increased complexity raises the beauty rating, until an optimum level is reached, with increased complexity beyond this level leading to a decrease of aesthetic preference.

Berlyne's theory of aesthetic appraisal (1966; 1971) is founded on the assumption that humans seek out stimulation and information to either gratify their curiosity (specific exploration) or to simply overcome boredom (diversive exploration). Visual patterns, such as works of art, can provide for this need in that they afford a certain amount of novelty, complexity, or ambiguity. These 'collative' properties contribute to the arousal potential of a pattern, i.e., the amount of attention or excitement that a pattern can produce. Beauty or preference is hypothesized to be related to arousal potential in an inverted U-shaped manner.

Berlyne's theory initiated a considerable amount of research on the relationship between preference and arousal potential, the latter variable often being operationalized in terms of one of the collative variables, i.e. complexity. However, besides evidence in favor of the predicted inverted U-shaped function (see Berlyne, 1971, pp. 181-213, for a review), in a number of other studies U-shaped, monotonic, and bimodal functions were found as well between these variables (see Boselie & Leeuwenberg, 1985, for a review of these studies).

Berlyne's model can be conceived of as a version of the famous 'unity in variety' principle (Walker, 1980). This principle holds that the greatest pleasure or beauty is arrived at by as much variety, novelty, or complexity (arousal inducing variables) as possible, counteracted with a maximum of unity, lawfulness, or order (arousal reducing variables). Various previous attempts to mathematically express beauty (M) by some function of order (O) and complexity (C), such as \( M = O/C \) (Birkhoff, 1933) or \( M = O \times C \) (Eysenck, 1942), however, had failed to predict the rated beauty for polygons (e.g. McWhinnie, 1968). Following on these attempts, Boselie and Leeuwenberg (1985) also adopt the unity in variety principle, but relate it to another of Berlyne's collative variables, i.e. ambiguity.

Like complexity, ambiguity is often held to be responsible for exploratory behavior (Berlyne, 1971). Ambiguous patterns induce a response conflict and thereby invite the perceiver to prolonged, active viewing to resolve the conflict. Nicki, Lee, and Moss (1981), for instance, showed that viewing behavior increased with the ambiguity of cubist paintings. Ambiguity in works of art can therefore be regarded as a powerful means to ensure that a perceiver actively explores a work of art. There are however various ways in which a pattern can be made ambiguous and not all of these types will be conducive to preference or beauty.
When a pattern has several alternative meanings, disjunctive ambiguity concerns the case where the meanings are mutually exclusive (Attneave, 1971; Kaplan & Kris, 1948). Disjunctive ambiguity could be described as the existence of two mutually exclusive global structures, between which perception alternates. This type of ambiguity is for instance observed in the Necker cube (Figure 4.2), the two rivalling interpretations are globally consistent orientations of a 3D cube. That disjunctive ambiguity is caused by switching between alternative global structures, is suggested by Attneave (1971), who showed that groups of Necker cubes do not reverse independently of each other, but all simultaneously. At each moment any one of these interpretations will dominate leading to a stable, but uninteresting percept. Disjunctive ambiguity is therefore often regarded as detrimental to the beauty of a pattern (e.g. Boselie, 1983; Hochberg, 1978).

\[ \text{Figure 4.2. Disjunctive ambiguity: Necker Cube with two rivalling global interpretations, referring to alternative views from below and from above, which are mutually exclusive.} \]

The focus of Boselie and Leeuwenberg’s (1985) model was, however, on conjunctive ambiguity. This type of ambiguity is arrived at when separate meanings are jointly effective for the interpretation of a pattern and is exemplified in Figure 4.3. Conjunctive ambiguity must be understood as the co-existence of a local and a global structure in the percept. If the local organization is predominant perceptually, still the existence of the global one is sensed, as providing additional consistency to the figure. If the global one is predominant, the local structure will add richness in detail. Whichever of the two interpretations is predominant, the other one yields additional regularities that can be perceived without weakening the other (Boselie & Leeuwenberg, 1985). This hidden order or ‘surplus structure’ contributes to the aesthetic appeal of the pattern and conjunctive ambiguity is therefore regarded as conducive to aesthetic preference (e.g. Arneheim, 1974; Berlyne, 1971; Gombrich, 1959).

Based on a coding theory of perceptual structure, Boselie and Leeuwenberg (1985) have adopted a way of describing order, complexity and surplus structure, which could neglect the time course in perceiving art. The reason why Boselie and Leeuwenberg (1985) were able to neglect the time course is, that they restricted themselves to simple polygonal figures of which all structure is instantaneously transparent. Real works of art will, however, often hide a greater number of additional regularities and whether an observer actually perceives the surplus structure depends on his aesthetic insight. This insight is prepared by
perceptual repetition, i.e., prolonged active inspection and exploration. It may take a considerable amount of active viewing before the surplus structure of a piece of art emerges. The inception of an aesthetic insight could be equated to the perceptual reorganization that appears spontaneously to occur under prolonged, active inspection of a visual structure.

The time course, by which the surplus structure may become apparent, may therefore be relevant for the aesthetic appraisal. For this reason, a theory of perceiving art should take the dynamics of perceptual reorganizations into account, which occur under prolonged active viewing. The following conjecture on the dynamics of art appreciation could be proposed: a work of art must on a first inspection reveal a structure that invites prolonged, active viewing. This could be achieved if the structure initially perceived has conjunctive ambiguity. The conjunctive ambiguity leads to aesthetic appraisal when, as a consequence of prolonged active inspection, the surplus structure is detected. When, after prolonged viewing, surplus structure reveals itself to the perceiver, the aesthetic appreciation provides an intrinsic reward for the effort invested. cf. Berlyne's principle of 'arousal jag' (Berlyne, 1971) refers to a situation in which a temporary rise in arousal-viewing effort- is pursued for the sake of the pleasurable relief that follows.

**Figure 4.3.** Conjunctive ambiguity. The figure can be perceived in different ways; most likely the mosaic of hour-glasses and diamonds is perceived. Only later a 3D orientation will be seen in the figure (two cubes, viewed from above). Hence, the 3D organization is a global surplus structure of the local mosaic.

Surplus structure, in the presently proposed view, is not a static stimulus characteristic but is understood in relation to perceptual reorganization. This notion does not provide a recipe for how to provoke the perceptual reorganizations that lead to aesthetic appraisal. It could safely be assumed, however, that the artist has intuitive knowledge of these processes, way beyond the best characterization any present theory could provide. Introspective reports by artists are, however, notoriously uninformative on this knowledge and on how it is applied; the Dutch painter Karel Appel on this subject: "I just mess around". This makes likely that the artist relies on what he sees and on the processes of creative imagery, rather than on goal-directed metacognitive rules. The knowledge applied is therefore unlikely to show up in think-aloud protocols (Ericsson & Simon, 1980). Rather than using stored declarative knowledge, the artist will exploit the capacity of the perceptual and imagery system to reorganize. A study of the processes involved in making abstract art, will therefore have to consider the way, how these processes work in perception and imagery.
The Perception of Structure

If the artist wants to create conjunctive ambiguity, (s)he must create a pattern in which independent local and global structures coexist. How are these structures to be described? This problem was dealt with first by the Gestalt psychologists. The Gestalt principles of organization, such as the laws of proximity, similarity, good continuation and closure (Figure 4.1) describe the spontaneous, direct experience of structure. These descriptive notions were explained by a theoretical principle of Prägnanz. This principle was radically holistic; Prägnanz is a property of a global visual field. In other words, such a principle may be useful to describe global structure, but will have difficulty in explaining what local structure is. Holistic concepts are notoriously hard to define. In the heydays of Gestalt psychology, electrostatic field theory was the only approach available. It was easy to disprove a role for electrostatic brain fields in visual field organization and this discredited the whole approach.

Figure 4.4. Illustrations of Gestalt principles of organization. Proximity (A), Similarity (B), Good continuation (C), and Closure (D).

Too holistic an account of perception would ultimately make the context prescribe what we see in a situation. This isn't always the case; even within a single object, perceivers may selectively attend a component and neglect its relations with other parts of the figure (Peterson & Hochberg, 1983). The notion that elements of a local or global structure can be attended separately runs against the radical holism of the Berlin school of Gestalt psychology. At least one branch of Gestalt psychology, called the Graz school (Von Ehrenfels, Meinong, Benussi, Metelli, Kanizsa), never committed itself to the radical holism of the Berlin School (e.g., Kanizsa, 1994; Von Ehrenfels, 1890). If the time has come to rehabilitate Gestalt psychology (Epstein, 1988), Graz school notions will have to be among the first to be considered, as allowing for strategic influences on perceptual organization phenomena.
Selective attention for elements results in an overall piecemeal mode of perception, which is characterized by a loose integration of the parts, with large room for inconsistency between them. Kanizsa (1970) used this principle to show that perception is often more local than Gestalt psychologists, at least those of the Berlin school (Koffka, Köhler, Wertheimer) would expect. In Figure 4.5 (adapted from Kanizsa, 1970), the global structure is a checkerboard, of which one square is colored black. This regularity is not experienced perceptually. Instead the local structure, a black cross in a checkerboard is seen.

The strategic, attentional character of local versus global perception can be experienced even in Figure 4.5, which Kanizsa had designed to show the contrary. By attending the diagonals, the global structure in Figure 4.5 is reinforced and can in fact become dominant. Spatially and functionally local and global coincide in this example. In this case, because attention is given to regions which are segmented on the basis of spatial proximity (Compton & Logan, 1993; Van Oeffelen & Vos, 1982). If another criterion for functional organization had been used, for instance, symmetry or transparency, as in Figure 4.6B, spatially and functionally local and global are dissociated. For instance, Figure 4.6A is spatially more global than the lower one, but functionally more local. For the discussion of structure in art, as well as in general for issues in the perception of structure, the functional notion of local and global is considered of more importance than spatial characteristics, even though spatial scale itself can sometimes be a constitutive aspect of a work of art (e.g., Klaas Oldenburg).

![Figure 4.5](image-url) Kanizsa's figure: a cross instead of a square occludes the checkerboard.
Note the upper configuration is spatially more global than the lower one, because the upper one is larger. The lower configuration is functionally more global than the upper one, because the upper one imposes stronger constraints on the components.

The functional notions of local and global belong to a broader processing distinction, which also includes processing strategies and styles. These are usually distinguished in terms of analytic vs. holistic processes. Analytic strategies and styles imply the perception of separable elements, intraconceptual relationships or serial structure. More in general, we find on the analytic side: sharpening of categories, verbal coding, high conceptual differentiation, serial processing. Holistic processing implies: the perception of global Gestalt structure, integral dimensions, family resemblance, interconceptual relationships (Drews, 1987) and, more generally levelling of categories, visual codes, low conceptual differentiation, loose analogies, and intuitive judgement (Miller 1987). The construct validity of the analytic-holistic distinction is widely acknowledged (Beyler & Schmeck, 1992; Koller, Rost, & Koller, 1994). Beyler and Schmeck (1992) compared several potential measures of the analytic-holistic construct compiled from surveys and questionnaires. Studies show a convergence of these measures, and a divergence of other ones.

Underlying these functional distinctions, a distributed neural representation system may be assumed. In such a system, representational structures are formed by dynamic binding of activated units (Von der Malsburg & Schneider, 1986). Under such generic constraints, perceptual structure is likely to grow from loose, independent elements, to a coordinated, global activation pattern. The autonomous dynamics of perception therefore is likely to be a local-to-global dynamics (Biederman, 1987; Sekuler & Palmer, 1992). The effect of both processes is functionally the similar, and could be addressed as the principle of hologenesis (van Leeuwen & Bakker, 1995).
Most authors today consider a general principle for perceptual organization impossible. Because of computational complexity considerations (Tsotsos, 1993), most rely on domain-specific, special mechanisms, such as for shape from shading (e.g. Ramachandran, 1990), symmetry (Wagemans, 1995), colour, etc. The principle of hologenesis is offered as an alternative to the view that all these special mechanisms have no uniform principle in common.

The constructivist approach to perception (e.g. Gregory, 1981; Hochberg, 1978) would agree with the observations on which hologenesis is based, but would interpret them differently. In this view, perceptual structure is synthesized from elementary sensations. Perception, in this view, is predominantly involved in the creation and maintenance of global perceptual structure. This does not imply that global perceptual structures are always predominant in perception (Peterson & Hochberg, 1983). Global perceptual structures require the involvement of memory schemes (Hochberg, 1978). These schemes are not specific to certain combinations of sensory features. Rather they are to be regarded of abstract classificatory mechanisms. In other words, the perceptual schemes of constructivism are global and abstract and contrast with the specific and local sensory patterns.

There are reasons to assume that the identification of local and global with, respectively, sensory stimulation and schematized classification, is not useful for the study of abstract art. By its very definition, abstract art defies object classification and for this reason, it appears better to associate the notion of global structure with dynamic self-organization, rather than with stored schemes.

There are other, more important reasons why a dynamic approach appears able to deal with the perception of structure in art better than a constructivist account. According to a constructivist view, all formation of structure would be a process of synthesis. In synthetic processes, either components are joined to form a global whole, or the whole is retrieved as a scheme from memory. During this process, there is no reconsideration of the components. Once a stable global structure is formed by a constructive synthesis, perception would be completed and component structure will not be altered.

Yet, perception may be not as stable as constructivist accounts would presume. If perceptual activity is prolonged after a global structure has been found, a phenomenon may occur, which resembles what occurs when an ambiguous figure is presented. After a certain time, the percept reverses spontaneously. It appears, that perception does not exclusively involve synthesis processes, but also processes that lead to the destruction of a given structure, and subsequent transformation of its components, which may sometimes lead to the distinction of novel components. These processes have been called analysis. Therefore synthesis is not a sufficient account of the formation of global structure in perception. This formation process is therefore addressed as resulting from the combination of holistic and analytic processing. The combination of these processes provides perception with intrinsic instability.

The intrinsic instability of perception has a functional significance. Too much stability would make perceptual systems inflexible, i.e. unlikely to perceive new structure spontaneously (Grossberg & Mingolla, 1985). Too little stability would make it impossible for the perceptual
system to detect in a dynamically evolving environment. In dynamic systems, such as neural network models for perception, it is possible to implement a subtle interplay between those forces which approach and those which diverge from stably established perceptual patterns (cf. Skarda & Freeman, 1987). Due to these opposing forces, even a simple line drawing can only lead to an apparently stable image for a certain, restricted time only (Kelso, 1995; van Leeuwen, Steijvers, & Nooter, 1995). The global structure seems to dissolve, giving rise to alternative organizations, which sometimes lead to the discovery of new and unanticipated global structure. Perception, therefore, is characterized best as an ongoing process, driven by the opposing tendencies to create global structure and its break-up by analysis.

The findings are in overall agreement with a notion of perceptual attractiveness as the result of two opposing forces or tensions (e.g., Apter, 1984; Arnheim, 1974; Berlyne, 1970, 1971; Kreitler & Kreitler, 1972; Martindale, 1981). One of these forces is equated to relaxation, the search for a stable image in perception. This tendency emphasizes familiarity, stability, and reduction of complexity. The other tendency is a tension-heightening striving for novelty or complexity to preclude habituation and to enable processing of incongruous or novel stimuli (Hekkert, 1995). This consensus notion of tension in the perception of art, therefore, could be understood on the basis of the perceptual mechanisms as presently described. This preludes on what we have to say about the role of sketching with respect to surplus structure. If imagery produces a global structure, the sketch is to create local structure. Sketching in abstract art, may therefore have the role of creating local from global structure, as is required for the perception of surplus structure.
The Creative Process

Since imagery perception and imagery share resources (Kosslyn, 1980), the same processes involved in the creation of structure in perception are likely to be found in imagery too. Like in perception, a distinction in creative processing could be made; on the one hand, there are processes in which components are joined together or separated from each other, but maintain their already known structure. In the previous paragraph, these processes have been called synthetic. This suggests that imagery processes could well be described with notions borrowed from constructivism. At the same time, synthesis was not considered sufficient to account for perceptual processing. This may suggest that the processes of imagery constitute a subset of the perceptual processes (Verstijnen et al., submitted-b). The processes that are part of perception, but not of imagery, were called analytic (Verstijnen et al., submitted-a).

Synthetic processes, in which components maintain their structure, are easy in imagery. Some of the synthetic processes could be called creative, in the sense that a figural combination results in a new, unanticipated configuration. Finke and his colleagues (Finke & Slayton, 1988; Finke, 1990) asked subjects to synthesize elements into a recognizable object before their inner eye. For example, a letter "j" and a letter "D" can form an umbrella. Finke showed that subjects not only were able to create familiar objects but also could discover new unanticipated creative ones. The newly synthesized objects, however, respect the structure of its original components; the J and the D are preserved as components in the newly established configuration.

A synthesis in which the parts are joined could easily be imagined in the reversed order. This process maintains the original components and does not lead to novel ones. It is therefore not considered relevant for creative processing. The notion of creative synthesis is therefore exclusively used to refer to processes, in which initially separate objects are joined to form a new configuration.

Another situation occurs, when the original components disappear, as soon as a configuration is formed. For instance, when a mosaic is formed as in Figure 4.7. Putting two components of a mosaic together in a synthesis process, will preserve the two as separate structures. When the components are not preserved as separate figures, this transformation was identified as analysis (see Figure 4.7). The transformation of components is difficult in imagery (Verstijnen et al submitted-ab), because it requires the production of unanticipated components.
Figure 4.7. If two components of a mosaic are joined, this is regarded as a synthetic transformation which is easily performed in imagery (A). If, however, the components become transformed, or completely disappear in the structure, this is considered an analytic transformation, which is difficult in imagery (B).

In the case of Figure 4.7, it could be disputed whether the bringing together of the components (synthesis), or the transformation in shading which leads to the dissolving elements (analysis), is the decisively creative step. Probably, both are needed to be creative. There are clear cases, however, in which the analysis constitutes the creative process. This is the case, when analysis is involved in the detection of novel components. Novel components are obtained, if the component structure of an image is transformed. For instance, in Figure 4.8, two hour-glasses will, on analysis, be shown to consist of two overlapping parallelograms. This process is called novel decomposition. Like the earlier-discussed form of analysis, novel decomposition is expected to be difficult in imagery, because it involves transformation of the components.

Figure 4.8. Novel decomposition as a form of analytic transformation which is hard to perform in imagery. The leftmost figure, initially synthesized from two hour-glasses, requires a novel decomposition in order to be seen as two overlapping parallelograms.
Sketching

The fact that synthesis in mental imagery can be useful as a source for creative discovery, raises the question why artists sketch. If imagery is such a powerful tool for creative discovery, why do artists and other creative people have to externalize their images and what contributions do these sketches make to invention? According to the distinction introduced before, the answer to this question may be based on the notion that creative processes involve synthesis as well as analysis.

Despite celebrated inventors' claims and notwithstanding Finke's findings, other researchers (e.g. Reisberg & Chambers; 1985, Reed & Johnsen, 1975) found discovery in imagery to be constrained. Chambers and Reisberg (1985) showed that subjects were unable to reverse an ambiguous figure (e.g. duck/rabbit) and detect the alternative interpretation in their image. Subsequent investigations (Hyman & Neisser, 1991; Peterson et al., 1992) with a similar paradigm also observed that discovery performances remained strikingly low. These results suggest that there are certain forms of discovery that cannot easily be performed in imagery.

Reed and Johnsen (1975) have shown that imagery is constrained in reinterpreting images, as compared with visual perception. These authors used a component detection task. Whereas discovery of parts coinciding with the global structures of the pattern was performed in imagery and perception equally well, performance in imagery was worse if the part did not belong to the global structure of the pattern.

The opposing conclusions of Finke (1993) versus Chambers and Reisberg (1985), and Reed and Johnsen (1975) could be reconciled on the assumption that two types of discovery exist, which are of different breed. Verstijnen et al. (submitted-a) argued that, whereas Finke's figural combination task predominantly involves synthesis, and leaves component structure intact, the tasks used in both Chambers and Reisberg (1985) and Reed and Johnson (1975) involve the identification of novel components. Subjects are required to restructure their image in a way, which involves new, unanticipated components. This process was identified as analysis (Verstijnen et al., submitted-a).

Finke's figural combination task does not require analysis, i.e. the initial structure of the elements stays intact when the synthesis is made. In the umbrella example this means that the component structure of each letter "j" and "D" is not violated. Finke's experiments, therefore, are in accordance with the suggestion that whereas synthesis is easy in imagery, analysis is difficult.

In the section on visual perception, it was discussed that visual perception meets no obvious difficulties in switching between alternative structural interpretations. Perceptual processing seems, therefore, to have a larger proportion of analytic processing. This may be related to the fact that images are stored in memory as global wholes (Hardcastle, 1995). During a sketch, the analytic visual qualities of the figure can be restored from the global
representation. If, for instance, the Kanizsa figure (Figure 4.5) is sketched from memory, the sketcher will begin drawing the checkerboard from the global structure and colour one square black. Despite this fact, once it is sketched, the local structure of the Kanizsa figure could be perceived. The sketch adds surplus structure to the image: if the image has retained only the global structure, the local structure is restored by sketching. Sketching is a form of interactive imagery (Goldschmidt, 1991), allowing to combine the synthetic abilities of imagery with the analytic abilities of perception. In general, this may be the reason that creative processes are facilitated by externalization.

In two series of experiments this hypothesis was put to a test. The first series used a Reed-like component detection task (Verstijnen et al., submitted-a), the second series used Finke’s figural combination task (Verstijnen et al., submitted-b). In both series expert sketchers were used as subjects. It may be concluded that synthetic processing is easy and frequent in imagery and cannot be enhanced by sketching. Analytic processing, by contrast, is difficult in imagery and benefits from sketching.

Results of these experiments and the studies of aesthetic appraisal and visual perception, converge in a description for sketching in the making of art. From the field of aesthetic appraisal it was concluded that sequence of sketches should reveal the aim of the artist to create surplus structure, by means of conjunctive ambiguity. This ambiguity implies that multiple structural interpretations have to be created. Both synthesis and analysis are likely to be involved in the creation of these structures.

Imagery can perform synthesis, and therefore does not require support of sketching. But the creation of local structure requires sketching and perceiving the result of the sketch as an interactive activity. Perception and imagery have complementary roles in this process. The end-results of synthetic processing in imagery will be reflected already in the first sketch made. Subsequent sketches will reflect the analytic changes in component structure, that give rise to surplus structure.
The Time Course of Surplus Structure

Creation of surplus structure is a long-term process, when compared to perceiving surplus structure. Therefore, not only microdevelopment of structure will occur in the making of art, but also development over a larger time scale may take place. Goldstone, and Medin (1994), and van Leeuwen, et al., (1988) described the evolution of a percept in time frames, roughly identical to the present conditions of art creation. These processes showed a development from an early preference for local structure, to a later preference for global structure. A similar development is expected for sketching; the earlier sketches will have more local structure and the later ones, more global structure, this as a result of the accumulation of synthesis of global structure in creative imagery. In the course of sketching, imagery produces increasingly global structure. For this reason, the analytic transformations used in the early sketches will differ from those in the later ones. As a result, different forms of surplus structure will be observed in subsequent sketches. The present paragraph will focus on these different forms of surplus structure and will introduce some techniques by which these can be achieved in sketching. A more extensive treatment of these techniques will be given in the next paragraph. The work of P. Kleijne concentrates on the use of mosaic vs. occlusion interpretations. This paragraph will therefore be focused on these techniques.

The first sketches will reflect the result of a primitive synthesis. The formation of a mosaic out of loose elements (see Figure 4.9) could be understood as such a primitive synthesis. That mosaic interpretations are the result of a primitive synthesis is suggested from perception studies. Sekuler and Palmer (1992) presented occluding figures (Figure 4.10A) for short durations (50-400 ms) before interrupting viewing by presenting the next figure. The occluding figures were perceived as a mosaic (Figure 4.10B) for the shorter durations (below 200 ms) and as an occlusion (Figure 4.10C) for longer ones. The earlier mosaic interpretations are more local than the later occlusions, which are often completed according to their global structure. The early occurrence of mosaics in imagery synthesis could therefore parallel the early occurrence of mosaics in the micro-evolution of a percept.

\[ \text{Figure 4.9. A synthetic process of combining figures in a mosaic leads to the formation of a new configuration.} \]
Figure 4.10. The figure synthesized in A has surplus structure of type 1: besides the mosaic interpretation depicted in B, an occlusion interpretation C is possible.

During this process, individual features change: what were corners of a shape in the initial mosaic in Figure 4.10B, lost this function on emergence of the occlusion interpretation of Figure 4.10C. The creation of an occlusion interpretation from a mosaic can, therefore, not be understood entirely from synthesis, but requires analytic processing as well. Analysis is less likely to occur in imagery, and will require externalization. The transition will therefore be observed in a sequence of sketches. In producing these sketches, the artist will attempt to create surplus structure, an equilibrium between alternative local and global structures. In this stage of the creative process, this will involve the local mosaic and the global occlusion. For that reason, the first type of surplus-structure will involve a mosaic-occlusion ambiguity (type-1 surplus structure).

As an illustration of how type-1 surplus structure could be realized in an occlusion interpretation, consider Figure 4.11. Once an occlusion interpretation has been recognized, it could be further strengthened, for instance by another analytic transformation, which makes the elements of the occlusion more consistent.

Figure 4.11. Surplus structure of Type 1 is created. The occlusion interpretation of the mosaic is strengthened by making its components more consistent to each other with respect to location, colour and size.
The second form of surplus structure will arise after an occlusion interpretation has already been formed, and is thus expected to emerge later than type-1 surplus structure. Van Lier, van der Helm, and Leeuwenberg (1995) studied occlusion interpretations. They investigated the controversy whether completions are made according to local or global perceptual structure. Whereas on the one hand Kanizsa and Gerbino (1982) suggest that perceptual completions are performed locally, i.e. they are performed on the basis of the principle of good continuation. Buffart, Leeuwenberg, and Restle (1981) have argued that the global structure of the figure determines the completion. In Figure 4.12, alternative possible completions of a figure are shown. The completion in Figure 4.12a is in accordance with the global regularity of the components; the one in Figure 4.12b is in accordance with local element structure. Using a formal simplicity metric to calculate the complexity of alternative patterns, van Lier et al. (1995) obtained a reasonable prediction of the preference for a local or a global completion, depending on the relative simplicity of either structure. From this result, it could be concluded that occlusion interpretations are not exclusively made according to local or global structure, but that it depends on the relative simplicity of both. This implies that in occlusion interpretations, local and global structure can occur as rivals, if their structures are equally simple. The importance of this result for our present considerations is, that surplus structure can also be realized by manipulating the relative simplicity of alternative local and global completions.

![Figure 4.12](image)

Figure 4.12. Alternative, global (A) and local (B) completions.

In Figure 4.13, it is illustrated how a figure can establish surplus structure by an analytic transformation on a (global) occlusion. Originally, the structure consists of two occluding squares. The occlusion interpretation has lost its original consistency as a result of the transformation to restore the global occlusion interpretation, it must now be assumed that the background figure peaks through a slit in the foreground. By bringing a part of the background square to the front, in the form of a small triangle, a novel component is formed, with which there is local structure rivalling the global occlusion interpretation. This suggest
the interpretation of a local occlusion. The existence of a local occlusion interpretation, independent of the global one is a new form of surplus structure, called surplus structure of type II. Examples of this kind of ambiguity can be found in Penrose and Penrose, (1958) in the early work of Reutersvärd, (Reutersvärd, 1985), and in the work of Maurits Cornelius Escher of course.

Figure 4.13. Surplus structure of Type 2 is created by a modification on a global occlusion interpretation.
Examination of Series of Sketches by Paul Kleijn

Two types of surplus structure have been distinguished. We now turn to the work of the artist, Paul Kleijn, who will be shown to use these surplus structures. Moreover, he uses them in the predicted order of Type I before Type II. The artist painted and used charcoal, sometimes in combination with masking techniques. Figure 4.14A shows the first sketch of the series of sketches made by Paul Kleijn. It contains a main square with four surrounding triangles. This sketch is clearly a mosaic, although some overlap may exist of the main square on the black M-shaped form at the bottom of the sketch. The surrounding triangles have different coloring and imprecise locations with respect to the main square and therefore could be said to be aligned to the main square independently. The presence of a mosaic structure corresponds to the primitive synthesis expected to occur in the earliest stage of imagery and sketching. The aligned triangles may already seem to suggest a second square occluded by the main square. This occlusion interpretation is not yet very strongly represented in the first sketch, and therefore this sketch does not show much surplus structure. In having a mosaic, however, it fulfills one of the preconditions for surplus structure of Type I.

In the next sketches (Figures 4.14B and C), we may observe that the occlusion interpretation is successively strengthened. In this process, an analytic transformation is observed, in which the individual triangles dissolve: in Figure 4.14B, they are given an identical green color (as in Figures 4.7 and 4.12). At the same time these triangles are more precisely located with respect to each other, which further enhances the suggestion that they form a square, occluded by the main square. On top of the main square a parallelogram (a) is introduced, which further enhances the depth of occlusion. Also the black M-shaped form at the bottom of the sketch has become an occluded figure. Parallelogram ‘a’, interpreted as being on top of all other forms, seems to be aligned as a mosaic to a figure in the background, a black rectangle ‘b’. Surplus structure of Type I could be said to be approached in Figure 4.14B. Occlusion dominates, but the sketch combines independent mosaic and occlusion interpretations.

The sketch in Figure 4.14C still maintains these aspects of Type I surplus structure. In addition, the first signs of surplus structure of Type II begin to appear. This form of surplus structure was identified as a conjunctive ambiguity between a local and a global occlusion interpretation. Because the global occlusion would normally be predominant, it is weakened by analytic transformations, making it inconsistent. We distinguished three analytic techniques used by the artist to establish this impression:

1. The suggestion of continuity through fusing in colour a form on top with a form in the back.

2. The suggestion of continuity through continuation of a form underneath a second form that’s not adjacent in depth.

3. Through moving a part of a form, that is currently partly covered by other forms, to the front (already introduced in Figure 4.13).
The first two techniques can be observed in Figure 4.14C. The sketch in Figure 4.14C introduces a new form, labelled 'a'. Through fusing of rectangle 'a' on the foreground with the M-shaped form 'b' in the background, a globally inconsistent occlusion is introduced, according to the first technique. The second technique is applied in the introduction of form 'd' in Figure 4.14C. Because of its width and colour, it seems as if form 'd' is an extension of 'c' and seems to peek out underneath 'b', although this is impossible because 'c' seems to be on top of 'b'.

The sketches in Figures 4.14D and E illustrate the third technique. Form 'c', being a part of the (suggested) green square underneath the white square, is being moved to the front, and now overlaps the front form 'a'. In Figure 4.14D this is done somewhat hesitantly, but in Figure 4.14E, this overlap clearly shows. Both sketches also show a stronger conjunction of form 'a' and 'b' than in Figure 4.14D. The first technique to obtain Type II surplus structure, which started with Figure 4.14D, is still continued to be applied in these sketches, gradually extending in force. The gradual extension of the conjunction across Figures 4.14D-F suggests a slowing down in approaching the critical, equilibrium point.

Nevertheless, the attempt to obtain Type II surplus structure appears to be unsatisfactory to the artist. Figure 4.14G shows an attempt to reintroduce elements from the first sketch, for instance the flanking edges of the initial sketch reappear. But these later sketches do not show conjunctive ambiguity any more. For his central structure, the artist seems to have passed beyond conjunctive ambiguity. Instead, the central figure now shows a recursive hierarchic structure. The global, recursive structures that predominate in his last sketches (Figure 4.14G-I) have a sterile appearance. Before he gives up, the artist makes one attempt to save this line of work. This attempt is quite drastic in terms of the dynamics. He returns to elements from his first sketch (the flanking structures) and aligns them to the central figure in a mosaic. The similarity with his initial sketch is striking. The artist thereby attempts to add the most local structure of his repertoire, to compensate for the global character of his central figure. But going back to the initial mosaic doesn't succeed in creating surplus structure with the central figure. The central figure is too strong and too self-contained a global structure, to form an occlusion with the flanking figures any more. As a result, there is no occlusion which could rival the mosaic. In other words, it is too late for an attempt to save the sketch by trying Type I surplus structure. Not even the attempt to mix the two, by adding little copies of the main figure to the flanking context, as in Figure 4.14I, has effect. The result is boring. The artist decides to give up working on this sequence.
Figure 4.14. An overview of the total series by Paul Kleijne.
Conclusions

Recent developments from the study of experimental aesthetics, perception and imagery were considered, in order to disentangle the processes that interact in creative art production. All these fields have shown increased interest in the processing of functionally local and global structures. Aesthetic appreciation of abstract art results from the apprehension of surplus structure. Surplus structure becomes in most cases only apparent by prolonged active inspection of a work of art, and its detection is considered to be facilitated by conjunctive ambiguity. Conjunctive ambiguity implies the coexistence of local and global structure in perception. Studies in the perception of structure have shown that two processes could be distinguished, synthesis, involved in the creation of global structure and analysis involved in its destruction and replacement by new, unanticipated forms. Imagery studies showed that the same processes of synthesis and analysis that operate in perception, are also involved in discovery in imagery.

Despite the similarities of these functions in the three different fields of our present investigation, also certain contrasts were observed. Whereas synthetic processing is as unconstrained in imagery as in perception, analytic processing in imagery is severely reduced. This contrast provided the major impetus for studying a series of sketches by an artist. These sketches were made in order to overcome the limitations of imagery in creating surplus structure.

In perception, both synthesis and analysis were found to be involved in the production of global structure. Constructivist accounts of perception would stress the synthetic aspects of perceptual processing. This would imply, that new wholes are obtained in a perceptual process by combining components. However, the process of creating global structure is not monotonic; often the creation of a global structure involves a perceptual reorganization. In order to obtain a global structure, some features must acquire a new meaning. This is exemplified in the transition from a mosaic to an occlusion interpretation during the microgenesis of a percept (Sekuler & Palmer 1992). Creation of global structure will therefore require analytic processing in perception. That analytic processing in perception is easy and frequent, can be shown from the spontaneous reversal of ambiguous figures, which require the breaking up, and subsequent reorganization, of an existing global structure. Such processes of analysis also occur under prolonged perception of a work of abstract art, allowing for the detection of surplus structure.

In imagery synthesis can be involved in the creation of both local and global structures. Synthesis leads to local structures, for instance when two separable components actually become separated by a mental transformation. Synthesis can give rise to an unanticipated global structure, when separated components are combined in imagery (Finke, 1993). Creative synthesis processes are considered to be involved in creating global structures.

Analytic processing is much more constrained in imagery. The detection of novel components by an analytic transformation is very difficult in imagery (Verstijnen et al, submitted-
ab). Therefore, creative processing in imagery will mainly involve the creation of global structure. In perception, the detection of local structure by creative analysis can compensate for the constraints of imagery. The creative processing of local structure is left to perception (Reed, 1974; Verstijnen et al, submitted-b).

Creative imagery can therefore be enhanced by externalization (e.g. sketching), if the creative process requires analytic processing. This is the case in the production of abstract art, if surplus structure is to be interpreted as a form of ambiguity between a more local and a more global alternative perceptual organization.

The artist, using sketching as a resource to create surplus structure, will operate within the constraints of the creative process. Because creative processing in imagery implies predominantly the production of global structure, a long-term tendency in creative production can be observed. Early creative synthesis in imagery will produce more local structures than later creative processes in imagery. As a result, different techniques to obtain surplus structure could be detected in sketching, depending on whether sketches are made early or late during the creative process.

Early strategies will appeal more to the local structure, and will involve the production of Type I surplus structure. This type of surplus structure was identified as a conjunctive ambiguity between a mosaic and occlusion interpretation for a pattern. Later strategies will appeal to Type II surplus structure. This type of surplus structure was specified as a conjunctive ambiguity between a local and a global occlusion interpretation for a pattern. In the sequence of sketches produced by the artist Paul Kleijn, type I surplus structure was produced in earlier sketches and type II in later ones as was in accordance with the prediction.

The question could be raised what could be made of Picasso's dictum: "I do not search, I find." In the light of the previous discussion, the suggestion can be done, that at the moment where synthesized mental products are externalized, the unanticipated new information that can be taken from the sketch, comes much to the surprise of the artist. Also in experimental setting (Verstijnen et al. submitted-a) many subjects reported this kind of Aha-experience.

This suggestion would imply an artist does not experience the quantum jump as often reported by celebrated scientists as, for example, Kekulé. Although parallels can be drawn between artistic and scientific discoveries, both are insightful and considered creative, differences can also be noted.

In the first place scientific discoveries are instantiated by inconsistencies in scientific theorizing. This inconsistency sets the boundaries to the solutions, and thus makes it a clear-cut problem. For example, for Kekulé, the kernel for his discovery of the benzene-ring was the detection of a molecule with an impossible ratio of elements, as contemporary theories prescribed the string form for organic molecules. In contrast, artists have the freedom to set their own boundaries, and even if set by environment considerable freedom remains.

In the second place, most scientific discoveries are not reported to pop-up after some way of externalization. Kekulé reported that he was seated before his fire place, and
was half asleep. He certainly was not sketching at that moment. Artists get frustrated if they are withheld from externalization, like the subjects (Designers) in the non-sketch condition of the reported imagery experiments (Verstijnen et al., submitted-ab).

Some of the anecdotal reports, however, allow for the possibility that external factors have served as an external trigger to drop certain structures. For example, Kekulé reported to see snakes in the fire. One snake was biting its own tail, hinting Kekulé to reconsider the organic-molecules-can-only-exist-in-strings-rule, and extend it with an option for ring-structures. Also Archimedes, sitting in bath, discovered a way of measuring the girth of an irregular object, by seeing the water-level rise through his own volume. But not all discoverers report such an external perceptual factor. Penrose, for example, was taking a bus for a geological trip. Although external perceptual factors might have caused him to find the solution to a mathematical problem that bothered him for a long time, he does not report so.

It can be the case that analytic processes can take place in imagery without external support, but that these take a long time to come to birth, as the durations of incubation periods suggest. In the light of this study, however, it can be suggested that it is useful to consider the role of perceptual cues in these processes, either purposeful as in a series of sketches by the artist Paul Kleijne, or accidental, as was de case in Kekulé's story.
CHAPTER 5

Conclusions

Abstract

The distinction of imagery processes in terms of analysis and synthesis was proven to be helpful in order to gain insight in the phenomena of discovery in imagery and sketching. Expertise and creativity were shown to have differential impact on these two processes. Each of the factors: analysis, synthesis, expertise and creativity, is highlighted separately in this chapter, with respect to their impact on sketching behavior.
Introduction

Celebrated inventors, like Kekulé and Einstein, claimed to have made their discoveries before the mental eye. This self-report evidence, however, is quite unrepresentative for the everyday practices of inventors, designers, and artists. These professionals often experience frustration when any form of externalization of their mental images is withheld. The question has therefore been raised what the advantage of sketching would be, given that discoveries could, in principle, be made in imagery only. This question needs to be addressed if idea-creation tools are to be constructed. For this reason, the psychological research in the field of visual imagery was surveyed for studies dealing with the issues of discovery in imagery.

Psychological research has provided ambiguous answers to the question whether discoveries can be made in imagery without externalization tools. On the one hand, Chambers and Reisberg (1985) argued for limitations on discovery in imagery, as compared to visual perception. In visual perception, reversal of certain ambiguous figures spontaneously occurs. Reversal involves the discovery of an unanticipated structure in perception. This type of discovery turned out to be difficult to perform in imagery. Similar restrictions on imagery were reported by Reed and Johnsen (1975). These latter authors showed that the extraction of an unanticipated component is difficult in imagery, as compared to visual perception. In consequence, a major benefit of externalizing mental images (e.g., sketching) would be predicted for these tasks.

On the other hand, Finke and Slayton (1988) obtained results in agreement with the self-reports of celebrated inventors. They showed that subjects could combine figural components in imagery into novel, unanticipated objects. For instance, a letter D and a letter J were combined in imagery to form an umbrella. From successful performance on such tasks it was concluded that subjects could discover unanticipated configurations in imagery. Following up on this research, Finke and his colleagues performed a series of figural combination experiments. Subjects in these experiments were able to create novel objects from a set of known, 2 and 3-dimensional components. These results demonstrate that Finke’s task can be performed without difficulty in imagery. For this reason, no advantage of sketching would be expected.

The contrasting expectations with respect to the role of sketching motivate a further study. It was hypothesized that Chambers and Reisberg, and Reed and Johnsen’s component detection paradigm on the one hand, and Finke’s figural combination paradigm on the other, addressed two different forms of imagery processes.

The Chambers and Reisberg (1985) and Reed and Johnsen (1975) paradigms share the common characteristic that components of a mental image have to be restructured in order to perform the task. In Chapters 2 and 3, the processes of discovery through restructuring components in imagery were called analysis.
Analysis means a transformation on the structure of the components of an image, as a result of which they acquire new properties. In Chambers and Reisberg (1985), analysis was needed to obtain an unanticipated new composition: the reversed image. For reversal, the configuration had to be abandoned. Its elements had to be related to each other in novel ways, creating a new part-whole structure, which implies new components. In Reed and Johnsen (1975), an unanticipated component had to be detected in a configuration. This requires also the abandonment of the existing configuration and the building up of a novel component from elements. This form of mental transformation is considered difficult in mental imagery.

Analytic processes appear to be less crucial for the other group of tasks, those of figural combination. In Finke and Slayton’s (1988) figural combination paradigm, components are combined into a larger whole. This mental transformation was identified in Chapter 3 as a synthesis process. Other than with analysis, synthesis processes leave the component structure intact. They are therefore easy to perform in imagery.

If synthesis is easy and analysis is difficult to perform in imagery, then tasks which differentially rely on these processes will differentially benefit from externalization. This forms a theoretical motivation for expecting a major benefit of paper-and-pencil sketching in, for instance, Reed and Johnsen’s component detection task, which requires analysis. Likewise, the notion that synthesis is used in Finke’s figural combination task is the theoretical motivation to expect little or no benefit of sketching for such a task.

Two series of experiments were performed, which used these contrasting tasks. Each series will be discussed separately in the following sections with their associated theoretical processing characteristic (analysis or synthesis). For a more detailed description of the experiments, the reader is referred to the earlier chapters. The following sections will concentrate on sketching behavior and its influences on analysis and synthesis. Expertise and creativity were shown to have differential impact on these two processes. Therefore, the relation of sketching to each of the factors: analysis, synthesis, expertise and creativity, will be highlighted in separate sections.
Sketching and Analysis

In this section and the following one on sketching and synthesis, only the results of expert sketchers are considered, results concerning novice sketchers will be dealt with in the section on sketching and expertise. The experts in the experiments were all industrial design engineering students having had at least two years of drawing education. The term 'experts' is used to stress the difference with 'novices', but is not meant to be interpreted as designating highly experienced sketchers. Vice versa, the novices, drawn from a population of first year undergraduate psychology students, are not expected to lack drawing skills completely. A comparison between novices and experts can be found in the section on sketching and expertise.

a. Analysis in the Component Detection Paradigm.

The first series of experiments, reported in Chapter 2, was inspired on the work of Reed (Reed, 1974; Reed & Johnsen, 1975). These experiments were performed with overlapping forms of which a novel component had to be extracted. For this reason, the task was called a component detection task. Prior to the experiment, subjects were informed about a set of components used. These were simple 2D wire-frame elements (e.g. square and diamond). During the experiment, configurations of overlapping components were presented, one at a time. Each configuration was briefly presented to the subjects. The short presentation time ensured that people were not able to grasp more information from the configuration than the identity of the components and their relative position. Hence, Figure 5.1 will be remembered as slanted square, and diamond with their lower edges aligned (Clark & Chase, 1972).

The task was to answer the question whether the configuration contains a subsequently presented figure, as a part. Some of these figures were indeed contained as parts in the configuration (targets) and others were not (nontargets). Among the targets, a distinction was made between explicit ones, which were components from which the figure was construed, and implicit ones, which were not used in the construction but resulted from the overlap between two or more components (see Figure 5.1).
Figure 5.1. An example of a configuration used in the component detection task. Detection of implicit targets requires analysis, because this figure will be remembered as a configuration consisting of a square and a diamond. No analysis is necessary to discover the explicit target.

The difference between implicit and explicit targets is relevant to the issue of analysis. Explicit targets can be extracted from the configuration without analysis, however analysis is to be performed if an implicit target is to be detected. This is the case, because the configuration is remembered as a combination of the original components. Analysis was therefore measured by the percentage correct on implicit targets. The percentage correct of explicit targets serves as a baseline, to determine the accuracy of performance without analysis.

Three variations of this experimental paradigm were administered; the first compared a group of subjects compelled to sketch with a group which was denied this strategy; the second experiment registered the spontaneous sketch behavior; the spontaneous sketch experiment; in the third the number of elements in a configuration were varied. A spontaneous sketching experiment approaches more closely the circumstances in which people normally turn to sketch.

The first experiment with this paradigm, allowed half the group of subjects to sketch (the with-sketch condition), and denied this strategy to the other half (the without-sketch condition). Figure 5.2 shows the results for both groups. Subjects who were allowed to sketch performed significantly better on analysis, i.e. finding implicit targets, than their counterparts in the condition where sketching was not allowed. The latter performed no better than chance-level (i.e. 50%).
Figure 5.2. Percentages correct detection of implicit components on the component detection task. Subjects not allowed to sketch (without-sketch condition) act on chance level (50%), whereas subjects compelled to sketch (with-sketch condition) raised their performance to a level, significantly above chance.

These findings contrast with those for explicit targets, see Figure 5.3. On explicit targets both the without- and the with-sketch group scored equally well. Although a slight surplus on explicit targets can be noted for the with-sketch group with respect to the without-sketch group, this difference is not significant. This surplus, which was noted for both experts and novices, could be explained on the basis of false targets only. Sketching in the case of explicit nontargets could have been helpful to inform the sketcher on whether he/she forgot this particular target or on whether it formed no element of the configuration, and thus was indeed a nontarget. Sketching in this case performed a similar role as reported in the Jacoby and Dallas (1981; Jacoby, 1985) studies, in which they showed that previously learned, but forgotten, words look more familiar.
Figure 5.3. With- and without sketch conditions in the component detection task do not differ on targets not requiring analysis, i.e. explicit targets.

Figure 5.4 illustrates the scores of the with-sketch group on implicit and explicit targets. Although a difference exists, this difference is not significant, and illustrates that performance on implicit targets can be raised to the level of performance on explicit targets with the aid of sketching. This, in contrast with the without-sketch group.

Similar phenomena were observed when spontaneous sketching was compared to compelled sketching. Performance on implicit targets was significantly improved by sketching (a significant correlation of .715), whereas sketching did not improve performance on explicit targets (-.034).

In the compelled sketching experiment, therefore, it was concluded that people cannot distinguish an implicit target from a nontarget when not allowed to sketch. The same could be concluded from the spontaneous-sketching experiments. Equal numbers of subjects turned to sketch spontaneously on implicit targets as on nontargets. This result demonstrates that prior to sketching, people barely have an idea of the occurrence of an implicit target.

To investigate individual correlates of the analytic processing ability, various tests were administered in the spontaneous sketch experiment: the Raven progressive matrices test, measuring intelligence (Raven, 1988), Witkin's embedded figures test (Witkin, Oltman, Raskin, & Karp, 1971), Mark's vividness of visual imagery questionnaire (VVIQ; Marks, 1973), Kunzendorf's aesthetic preference test (Kunzendorf, 1982), measuring creativity, and a measure of short-term memory-span.
Analytic processing (implicit target detection) correlated with intelligence, and creativity (this latter correlation will be dealt with in the section on analysis and creativity). Accuracy of performance without analysis (explicit target detection) correlated with intelligence, memory span, and embedded-figure detection. Vividness of imagery, as measured with Mark's VVIQ, did not correlate with any of the variables. This result can be attributed to the lack of validity in measures of vividness (Chara & Hamm, 1989; Reisberg & Heuer, 1988). It may also be the case that vividness of imagery is more important for inspection of imagery than for manipulation and transformation of images (Morris & Hampson, 1983).

Factor analysis on the above correlations showed that intelligence, short-term memory span, embedded-figure detection and the experimental measure of accuracy-without-analysis (explicit targets) are associated measures. The abundant representation of 'smart' variables in this factor, led to its name: the Smart Factor. Amount of sketching on implicit and explicit targets, creativity, and the experimental measure of analysis (implicit targets) formed a second, independent set of associated measures. This factor was called the Art Factor, because of the occurrence of 'arty' variables. The Art Factor was shown to be about 5 times as important for analysis than the Smart Factor (Verstijnen et al., submitted-a).

One of the constituents of the Smart Factor is memory capacity. The fact that the Smart Factor contributes only little to analysis, suggests that memory capacity is not a relevant determinant of the difficulty of analysis in imagery and therefore irrelevant for the motivation to sketch. This finding contradicts the intuitive idea that limitations in short-term memory trigger sketching behavior (Ullman, Wood, & Craig, 1990). To perform a more rigid test on this idea, a third experiment was performed, that focused on memory.
In this experiment, the number of elements of a configuration was varied. If short-term memory-span is irrelevant for sketching behavior, then, it was hypothesized, no change in performance is expected when the number of components in a configuration is raised (Cavanagh, 1972). Moreover, if implicit targets are used, the accuracy of detection will not depend on the number of components. Whether two or five components were presented, the number of spontaneous sketches was unaffected by the number of components. Also, accuracy of performance was independent of the number of components. It was, therefore, concluded that memory limitations are irrelevant for sketching behavior.

Many artists and designers, when asked for their motivation, ascribe a function of memory extension to their sketching behavior. The results of the present experiments contradict these introspective reports, instead they confirm the conclusion of the previous experiment that memory restrictions do not form the motivation for sketching. It cannot be excluded, however, that sketches may fulfill a role for retention on a longer term than the scope of the present experiments (Reisberg, 1985). In general, however, it may be concluded for the component detection task, that the extraction of novel components yields the decisive impetus for sketching, because this form of analysis is difficult to perform in imagery.

![Figure 5.5.](image)

Two examples of objects created in the figural combination experiments. The figure on the left is a shower for swimming-pool. The ball has to be pushed up to get a shower. This being hard, the shower will save water. On the right is a tool created for window-cleaners. It can be suctioned to the wall, and be used as a grip or a foot-rest.

The mean analysis score for the with-sketch group was significantly higher than that of the without-sketch group (see Figure 5.6). Thus, even though the products were equally creative, they were achieved by the without-sketch and with-sketch groups in different ways: sketching subjects make use of analytic strategies more frequently than non-sketching subjects.
b. Analysis in the Figural Combination Paradigm.

The second series of experiments, reported in Chapter 3, used a modified version of Finke and Slayton's (1988) figural combination paradigm. Before the experiment started, six possible components (cone, cube, cylinder, sphere, diamond, flat-square) were presented. Subjects were instructed to memorize them in combination with their names. During the experiment only the names of three components were presented at a time. Each time this occurred, subjects had to combine in imagery three simple components into an object. Half of the subjects was allowed to sketch during the imagery phase, the other half was denied this strategy. The resulting objects were rated on creativity, originality and practicality by independent judges. The creativity of the end-products of with-sketch and without-sketch conditions were compared.

It turned out that the creativity of the end-products was independent of strategy. This result was in accordance with the earlier conclusion by Finke and Slayton (1988), who observed that discovery in imagery was easy and frequent. According to the hypothesis, the reason is that the figural combination task is predominantly a synthesis task. Nevertheless, an investigation of whether analytic processing occurred as well was performed. For this purpose, in addition to the ratings, the objects were also scored on other properties.

For example, when a cube was one of the components presented, it was regularly found to be transformed into a rectangular box. In Figure 5.5b the diamond which originally was presented with as having a squared cross-section is transformed into one with a triangle as cross section. These kinds of transformations were considered to reflect analytic processing. Various kinds of these component transformations were scored. From those transformations, an analysis measure was computed. The analysis measure reflects the amount of transformations performed on the components. Individual subjects were scored on the analysis measure.
For instance, it may require analysis to form complex junctions between synthesized objects. Complex junctions are defined as those junctions, which require transformations of the components, in order to perform a fit; if one component has to fit to another, it is sometimes needed to perform a transformation of the components. Transformations on the components were considered analytic transformations. For that reason, complex junctions are indicative of analytic processing. Interestingly, in the without-sketch conditions, the number of complex junctions of 3D differed not from that in the with-sketch conditions, when averaged across all situations. This measure, however, included complex-junctions hidden in the back of the object. When only visible complex junctions were considered, their number in the with-sketch condition was significantly above that of the without-sketch condition. It may be concluded that the subjects in the without-sketch condition reach equally creative end-products, because they have a way around analytic processing, such as turning the complex junction to the back, when denied the possibility to sketch.

**Figural Combination Task 3D**

![Graph showing analysis score comparison between without-sketch and with-sketch conditions for 3D task.]

**Figural Combination Task 2D**

![Graph showing analysis score comparison between without-sketch and with-sketch conditions for 2D task.]

**Figure 5.6.** Analysis scores of the figural combination task as a function of whether the subjects were not allowed to sketch or were compelled to do so in conditions using 2D or 3D components. In both the 2D and 3D task, expertized sketchers are able to raise their performance when allowed to sketch.

The method to score analysis in the present task differs from that of the component detection task. In order to confirm that both tasks measure the same ability, it could be considered useful to compare individual scores across the experiments. Eleven subjects took part in the with-sketch groups of both the component detection task and the figural combination task. This made a check for the validity of the analysis measure in the figural combination task possible. A correlation was calculated between subjects' score on implicit
targets in the component detection task and their analysis score in the figural combination task. A highly significant correlation was found. The correlation shows that analysis is a personal characteristic, which is consistent over tasks and stable over time. This is an argument in favor of the validity of the measures of analysis in the two series of experiments and, in general, for the validity of the construct of analysis.

Based on the combined results of both series of experiments, it can be concluded that mental images are not inspectable in the same ways as pictures (Hinton & Parsons, 1988; Pylyshyn, 1973, 1981). The inability to perform analysis in imagery constitutes a major factor in the usefulness of sketching. Not only severe restructuring, such as novel decomposition, is supported by sketching, also lighter forms of analysis, such as occurred in the figural combination task, are improved by externalization. When mental images are projected in sketches, analytic information can be glanced from the sketches which could not be obtained from the mental images before the projection.
Sketching and Synthesis

In contrast to Finke's original version of the figural combination task, the one used in Chapter 3 was especially designed to test the influence of sketching on synthesis. This section, therefore, will mainly be concerned with the results of that chapter. Synthetic processing is reflected in the figural combination paradigm in the alignment of components of an object. Various forms of alignment are possible. For example, an object could have been created by a simple stacking of the components (Figure 5.5a) or one component could have been aligned horizontally and another vertically (see Figure 5.5b). Since each subject created multiple objects, different forms of alignment used by a subject could be scored. This score was considered to reflect the capacity to generate variety by synthetic processing. This score was therefore considered a subject's synthesis score. According to this measure, subjects in the without-sketch condition of the 3D task performed equal to those in the with-sketch condition (Figure 5.7).

![Figural Combination Task 3D](image)

**Figure 5.7.** Results of the 3D version of the figural combination task performance on a synthesis measure for the without-sketch and with-sketch condition.

A slightly different synthesis measure was used for the 2D version of the task. This measure, which was adopted from Anderson and Helstrup (1993ab) scored whether components were aligned in different orientations than initially presented. This measure was considered also to reflect synthesis, because this transformation leaves the component structure intact and, therefore, no analysis is involved, and the orientation of the components is prescribed by the configuration. On this measure, the sketching significantly deteriorated performance (Figure 5.8).
Figure 5.8. Results of the 2D version of the figural combination task: performance on a synthesis measure for the without-sketch and with-sketch condition.

On two different measures, equal or even deteriorated performances was reached as a result of sketching. This signifies that mental imagery is thoroughly capable of synthesis. Synthesis thus appears to be easy in imagery, and new information can be glanced effortlessly from a synthesized product, as was to be expected on the basis of experiments by Finke (e.g. Finke & Kosslyn, 1980; Finke & Kurtzman, 1981; Pinker & Finke, 1980; and also in Richardson, 1980). Or, as Spearman (1931) put it in his Principle of Relations: “When two or more items (percepts or ideas) are given, a person may perceive them to be related in various ways” (in Brown, 1989).

It can be concluded that no additional value is obtained from sketching if synthesis is to be performed. The fact that sketching can even deteriorate performance, as was the case in the 2D task, suggests that being compelled to sketch in conditions where it is not necessary will only distract the subject.
Sketching and Expertise

In most of the experiments in Chapters 2 and 3, experts (design students with at least two years of sketching experience) were compared to novice sketchers (psychology students with little sketching experience).

a. Expertise in the Component Detection Paradigm.

Only one major difference was obtained between experts and novices in the experiment with compelled sketching. On implicit targets in the with-sketch condition, novices performed significantly worse than experts (see Figure 5.9). In all other conditions, performance was equal. Sketching has helped experts in performing analysis for the purpose of detecting a novel component, but it failed to do so for novices, although also for novices a slight increase was noted.

![Component Detection Task](image)

**Figure 5.9.** Novices and expert sketchers perform equally on implicit target detection when they are not allowed to sketch, in the with-sketch condition, experts outperform the novices.

In an attempt to answer the question why sketching is not as helpful for novices as for experts, it is of importance that they provide the same scores on all the other conditions. The difference could not be attributed to a worse performance on, for instance, remembering the components of the configuration. Such a difference would have led to different scores on the explicit targets, which was not obtained, as Figure 5.10 clearly shows.
Component Detection Task

<table>
<thead>
<tr>
<th></th>
<th>Novices</th>
<th>Experts</th>
</tr>
</thead>
<tbody>
<tr>
<td>without-sketch</td>
<td><img src="image" alt="Bar graph showing synthesis score for novices and experts" /></td>
<td><img src="image" alt="Bar graph showing synthesis score for novices and experts" /></td>
</tr>
<tr>
<td>with-sketch</td>
<td><img src="image" alt="Bar graph showing synthesis score for novices and experts" /></td>
<td><img src="image" alt="Bar graph showing synthesis score for novices and experts" /></td>
</tr>
</tbody>
</table>

**Figure 5.10.** On explicit targets both the with- and without sketch group for both the novices and experts have matching performances.

On each and every single test, the novices test scores matched those of the experts. Therefore the difference between novices and expert sketchers can neither be explained by individual differences in ability, as measured by one of the various tests administered (intelligence, creativity, VVIQ, etc.). So neither the experimental scores, nor test scores provided a cue for the origin of the effect. For this reason, individual abilities, other than those relating directly to sketching, can not explain the differential effect of sketching for experts and novices.

An explanation is suggested, however, from a factor analysis, the same one as performed with the experts' scores (see the section on Sketching and Analysis: Analysis in the Component Detection Paradigm). This analysis applied to novices provided the same grouping of variables into a Smart and an Art factor for novices also. However, one notable exception was found. In contrast with the experts, for the novices virtually no influence was obtained of neither the Art nor the Smart Factor on implicit target discovery. Discovery of implicit targets was identified in previous sections as analysis measure. This suggests, that the lower scores of novices in the sketching condition for implicit targets, were due to their inability to perform analysis with the aid of sketches.

Differences in drawing skills may explain the novices' inability to use sketches for analysis. Expert and novice sketches differ sufficiently in appearance to warrant this conclusion: several industrial designers when asked to do so were able to reliably sort the sketches into expert and novice ones. A mean percent correct of 70% was obtained, suggesting that expertise can be glanced from the sketches.
b. Expertise in the Figural Combination Paradigm.

Novices took part in the 3D version of the figural combination paradigm only. As in the component detection task, the novices scored lower than the experts on the analysis measure in the with-sketch condition of the figural combination task, see Figure 5.11. In fact, novices even showed an opposite trend. Analytic abilities therefore seem to differentiate between experts and novices, and argue for analytic processing to be a fundamental constituent of expertise.

![Figural Combination Task 3D](image)

**Figure 5.11.** In the figural combination task in the without-sketch group matching performances were found for the novices and experts, but in the with-sketch group the novices are outperformed by the experts.

The synthesis measure did not differentiate between experts and novices. Although in both the without-sketch and the with-sketch conditions the novices scored lower than the experts, these differences did not reach significance, see Figure 5.12. The equal performances of both groups on the synthesis measure indicate that the expertise in sketching does not reside in synthetic abilities.
Figure 5.12. On the synthesis score in the figural combination task, all mean performances match, neither whether subjects were allowed to sketch, nor when they were expert sketchers.

The fact that analysis did differentiate between experts and novices in the with-sketch condition but not in the without-sketch condition, supports the claim that the distinctive ability of experts with respect to novices resides in performing analytic transformations with the aid of sketches. Synthetic abilities, however, were equal for experts and novices.
Sketching and Creativity

Since only expert sketchers benefit from externalization of images, this section returns to the achievements of expert sketchers, in order to study the relation between sketching and creativity.

a. Creativity in the Component Detection Paradigm.

In the component detection experiments, the Kunzendorf test of Aesthetic Preference (Kunzendorf, 1982), measures the mastery of “visual grammar”. Creative individuals, according to Kunzendorf, have a better mastery of “visual grammar”, which improves their ability to transform and restructure knowledge. In the introduction of this chapter, restructuring was identified as a form of analysis. It turned out that people who scored high on this test were far more likely to find an implicit target if they had spontaneously sketched, than the low scorers (a significant correlation of .654 was established, see Figure 5.13). This finding affirms the relationship between analysis and creativity.

Analysis, creativity, and sketching were found to constitute the Art factor. The finding of Art and Smart as two separate dimensions is in accordance with Wallas notion of “mental power” or “extraordinariness” (Wallas, 1985), which includes creativity and intelligence as separate factors (Cropley, 1991). Taken at face value, the independence of Art and Smart factors contradicts Guilford’s (Guilford, 1967), and Sternberg’s (Sternberg, 1988) idea that creativity is an aspect of intelligence. The Art factor, however, comprises analysis, but not synthesis. Guilford’s divergent thinking aspect stresses the synthesis aspect of creativity.
b. Creativity in the Figural Combination Paradigm.

The relation between synthesis and creativity was studied in the figural combination paradigm. The objects synthesized by the subjects were rated on creativity by independent expert judges (design teachers). Their ratings correlated highly among each other, in contrast to those of novice judges. This finding is in accordance with Amabile's operational definition of creativity; "A product or idea is creative to the extent that expert observers agree it is creative" (Hennessey & Amabile, 1988, p. 14; Amabile, 1982ab). For this reason, the expert ratings were considered a valid indication of object creativity.

The creativity ratings correlated significantly with both the synthesis score (a correlation of .482) and analysis score (.613) in the figural combination paradigm (only objects in the 3D variant were rated), see respectively Figure 5.14 and 5.15.

On the basis of synthesis and analysis scores, almost 70% of the variance in the creativity ratings in the sketch condition can be explained. The amount of explained variance provides an argument for the important role of synthesis and analysis in creative discovery in the figural combination paradigm. These findings contrast with the view expressed by Hennessey and Amabile (1988) that "There is one basic form of creativity, one basic quality that observers are responding to when they label something "creative"." (p. 15). Creativity, instead, seems to have at least two constituents, analysis and synthesis.
Figure 5.14. The relationship between subject's synthesis score in the figural combination task with their objects' mean creativity rating. For the with-sketch group only.

Figure 5.15. The relationship between subject's analysis score in the figural combination task with their objects' mean creativity rating. For the with-sketch group only.
Despite the fact that these two processes can explain as much as 70% of the variance in a single task and appear to have construct validity across tasks, the creative process will consist of more processes than the ones presently identified. In the experiments discussed, the components for synthesis or analysis were selected by the experimenter. This was necessary for experimental control on these processes. Outside the laboratory, the selection will be left to the creative individual. Individual preferences and differences in ability with respect to the selection of components for mental transformation will certainly constitute another important aspect of creativity which, however, is beyond the scope of the present sketching study.
General Conclusions

The distinction of synthesis and analysis throws new light on the issue of sketching. The synthesis process is easy to perform in imagery and is not supported by sketching. The analysis process is difficult to perform in imagery and is enhanced by sketching. That analysis is the difficult part, is confirmed by the fact that only experts can perform it with the aid of sketching. The two processes of synthesis and analysis together constitute important elements of the creative process (see Figure 5.16).

The Creative Process

![Figure 5.16](image)

The resulting model for the role of synthesis, analysis and sketching in creative discovery processes.

From the result of these studies, it is possible to provide recommendations for the construction of computer tools for sketching. In general, such tools must, like paper and pencil, be intuitive; i.e. the requirements for their use may not exceed the current level of expertise of their users. Paper and pencil are used spontaneously by both experts and novices, which implies that these tools must have a low threshold of accessibility and their use may not require specialized knowledge if they are to replace paper and pencil.

Since the synthesis process can be easily and rapidly performed before the mental eye, only the end-product of this process is likely to be found externalized. Synthesis itself is, according to the model, never an objective for externalization, and therefore will occur only in sketches intended to support the analysis process. Combining objects on a computer tool, therefore, must preferably pass effortlessly and super fast.

In addition, however, such tools must be helpful in excess of paper and pencil tools. The present studies suggest that appropriate support given to users, will have to allow users to raise their performance on the aspect of the task which is most difficult to perform, viz. analysis. In the analysis process, the sketcher draws one particular structure but does so in order to pick up novel structural components from perception of the sketch. Paper-and-
pencil sketches are often unspecified and vague, allowing for perceptual creativity to flesh out the structure. So a computer tool has either to support unspecified forms as input, or a flexible switching between various structural descriptions of the input after its creation.

Kolli and Stuyver (reported in Hennessey, 1994) studied the 3D CAD programs Pro-Engineer, Intergraph-EMS, Sculpt 3D and GIG3DGO. The first phase of this study revealed that with these state-of-the-art programs even a simple synthesis task with simple components is met with ample difficulty. Each program required considerable time for the alignment of components. Synthesis, therefore, did not proceed as effortlessly and fast as was required for these programs to be called intuitive.

In the second phase of this study, the subjects had to perform analysis on the components of the previously synthesized objects. How the components had to be restructured during this phase was not known beforehand to the subjects in the first phase. It turned out that some subjects had chosen a form of synthesis that did not allow any alteration of the components in the second phase. Therefore, they had to synthesize the object again before they were able to analyze it. This latter result indicates that analysis is a cumbersome job with current 3D CAD programs. These programs, therefore, failed to meet the requirement of being helpful as tools for idea-generation sketching in the early creative phases of the design process.

The problems of CAD programs with respect to analysis are illustrated in Figure 5.17. Suppose the leftmost figure was originally drawn on the computer as two overlapping triangles. A vertical translation of these triangles with respect to each other results in Figure 5.17a. This new configuration preserves the original components. This transformation, which is a form of synthesis, however, will not have been the motivation to sketch. But this transformation, according to the present investigations, is also easy to perform in imagery and so, there is no need for its externalization.

Sketching is performed for the purpose of analysis. The sketch will be inspected for emergent structures, which will be used for further processing. For instance, the sketch could also be perceived as consisting of four small triangles. In that case, Figure 5.17b illustrates a transformation which could have been the purpose of the sketcher; viz., the vertical translation of four small triangles.

With a traditional computer program, the sketcher will meet a difficulty in performing this transformation. The computer stored the figure on the left as two overlapping triangles, according to the way they were originally drawn. The program is not able to recognize the newly emerged forms (Mitchell, 1993). In order to perform the vertical translation, the sketcher has to redraw the whole configuration. This extra sketch hampers the creative process, because it brings stagnation at a moment where progress is wanted. This suggests that a "What about looking at it this way?" provision on computers, as suggested by Tatham (1995), would be a fruitful extension for contemporary computer tools.
Figure 5.17. The configuration on the left can be conceived as two overlapping triangles, in that case a results after vertical translation. But since sketching is used to restructure, a conception of the figure as four small triangles can be the result of sketching two overlapping triangles. Translation of these small triangles leads to b.

In current 3D CAD-programs, neither of the earlier-mentioned components of the creative process, synthesis and analysis, appears to be supported very well. Synthesis is time-consuming where it has to pass effortlessly and analysis is hardly supported at all. Current 3D CAD-programs, therefore, do not seem appropriate for supporting the creative process in the conceptual phase of design, where idea-sketches are usually made. Electronic sketch tablets, which, like paper and pencil, support unspecified input and leave the synthesizing and restructuring to the sketchers appear to be, for the time being, more appropriate electronic idea-creation tools. These tablets, however, lack support facilities for analytic transformations. The efficiency of these tablets for the purpose of idea-sketching could be considerably improved, however, if functions like the “what about looking at it this way”-facilities could be provided.

The research in the Chapters 3 and 4 was performed, in order to obtain recommendations from psychological research, on how to improve the efficiency of idea-creation tools. The present conclusions show, that such recommendations could give a direction to the further development of such tools, such as pursued in the IDEATE project (Hennessey, 1992). The wider impact for psychology of these studies, however, will be found in the field of imagery research. The studies showed that creative processes that are likely to take place in visual imagery will be synthesis processes. Creative processes less likely to take place in visual imagery are analytic processes.

The question could be raised, what the significance would be for these studies in the context of inventive cognitive processes. It has been acknowledged that such processes rely extensively on visual imagery. In the light of the previous conclusions on analytic versus synthetic in imagery, the question can be raised what could be made of the claims by some
of the famous creative individuals, that their discoveries were made in imagery. Kekulé claimed having made his discovery of the solution for the benzene problem while seated half asleep before his fire place. For Kekulé, the incentive to restructure his image was the detection of a molecule with an, at that time, impossible ratio of components.

Kekulé was dozing at the fireplace, Poincaré jumped on a bus (Poincaré, 1908), and Archimedes was bathing. These unusual locations illustrate what these stories have in common. All these innovators were struck by the solution for their problem at a particular moment where none of them had paper and pencil at hand.

One possibility is that the claims simply are wrong (Weisberg, 1988; Weisberg & Alba, 1991). Yet, they are taken very seriously in the creativity literature and therefore deserve our consideration. Secondly, there is the possibility that only synthesis and no analytic processes took place. This would also be unlikely, certainly in Kekulé’s case. Kekulé discovered that he had to drop the organic-molecules-can-only-exist-in-strings rule. In his days, this rule formed an essential component in the description of organic molecules. This component of the description had to be dropped, and therefore, the whole structure had to be reorganized. Such a process is likely to involve analysis. Also Archimedes, who had to decide on the volume of the king’s crown to find out whether it was made of pure gold or if the manufacturer had played a scurrilous trick and had mislead the king, knew that he had to drop as inappropriate all hitherto known rules for establishing volume, given the irregular shape of the crown. Only after dropping these rules as irrelevant, Archimedes had the option of finding an alternative. These operations involve the perception of novel attributes of the situation, an operation akin to analysis.

In most cases of cognitive innovation, the inventions involved getting loose of an original conception, which is probably identical to analysis. So far, the situation is parallel to the experiments; External conditions coerce the subject to restructuring. What then facilitated restructuring in these inventors in situations where no possibilities for externalization were available? Maybe, a wider interpretation of what occurred in the experiments of Chapter 2 will be helpful. In these experiments, when coerced to restructuring, subjects spontaneously turned to sketching, when allowed to. Their image would then be restructured in analogy to their sketch. In the experiments the detection was frequently reported to be very surprising. These surprising character of the detection matches perfectly the usual definition of insight, e.g. “...previously unseen and unexpected connections reveal themselves to the mind” (Langley & Jones, p. 177, 1988).

The role of analogy in creative thinking has been emphasized by many theorists (Perkins, 1981; Polya, 1945; Sternberg, 1977). Possibly, extraordinarily creative individuals were able to construct analogies within imagery, for which others, in more mundane cases, require a sketch. The occurrence of visual analogies is a familiar observation from the self-reports of these individuals. Kekulé discovered, after months of confusion, that he had to drop the molecules-can-only-exist-in-strings rule, by seeing a snake biting his own tale in the flames of his fire-place, and spontaneously envisioned this snake to be a organic molecule string. Archimedes saw the water-level of his bath raising while he stepped in, and although he must have taken many baths before, he suddenly realized the one to one relation of
raising water level and the volume placed in the water. Both individuals may have found their solution eventually through this vehicle of analogy, after a long incubation period.

Not all inventors, however, reported to have found the solution through analogies. Poincaré is the notable exception among these self-reports of extremely creative individuals. This suggests that even without an overt visual analogy, a restructuring of knowledge can take place. Anyhow, it took time before the restructuring took place spontaneously. Kekulé and Archimedes needed time for the 'sudden flash of insight' to occur as well; they happened to recognize an analogy in an event that took place in their environment. Hence the tentative but straightforward suggestion is that sketching provides the analogies necessary to shorten the incubation period. To speak with Archimedes, the motto will be:

Have a bath,

but make a sketch before the water runs cold!
REFERENCES


Kanizsa, G. (1994). Gestalt theory has been misinterpreted, but has also had some real conceptual difficulties. *Philosophical Psychology, 7*, 149-162.


Verstijnen, I.M., Goldschmidt, G., van Leeuwen, C., Hamel, R., & Hennessey, J.M. Discovery in imagery; synthesis can be done but analysis takes a sketch. (submitted-b)
Whether we wonder why we sometimes suddenly desire the back of an envelope to sketch out some ideas, or why an artist or designer usually needs a series of sketches before he/she is satisfied with the final product, or what properties have to be established in computerized idea-creation tools, the question we are really raising is why can’t we do it all before our inner eye. This thesis is concerned with a psychological study into discovery in visual imagery, and the augmentation of externalization.
The question; "Can discoveries be made before the inner eye?" has recently gained interest from experimental psychologists. Celebrated inventors, like Kekulé and Einstein, claim an affirmative answer. Despite this claim, some researchers, like Chambers and Reisberg (1985), and Reed and Johnsen (1975) found no or little support for an affirmative answer to this question. Others, like Finke and Slayton (1988), drew different conclusions from their experiments. These latter authors showed the possibility of creating new inventive objects, discovered before the mental eye. These opposing conclusions can be reconciled on the assumption that the discoveries are of different breed. The differences between the two experimental paradigms allow for this possibility.

Chambers and Reisberg (1985) showed in their experiments that subjects were unable to reverse the interpretation of an ambiguous figure (e.g. duck/rabbit) in their image. Subsequent investigations with a similar paradigm didn’t find completely zero performance, but discovery performances remained strikingly low. Similarly, Reed and Johnsen (1975) found that imagery is constrained in restructuring images, in comparison with visual perception. These authors used a part-whole detection task. Whereas discovery of parts coinciding with the structural description of the pattern (a component) was performed in imagery and perception equally well, performance in imagery was worse if the part did not belong to the structural description of the pattern (an element).

Both Chambers and Reisberg (1985), and Reed (1974) used tasks that involved a combination of identifying new elements and imposing new interpretations on old components of the structural description of an image. The conditions in which the difficulty arises involve that subjects at first held a certain interpretation of the structure of a pattern. Thereafter the task required the subjects to leave in imagery their perceived structure in favor of a novel structure, through which new unanticipated information had to be discovered. These kinds of structural image transformations were called analysis.

From both series of experiments it can be concluded that imagery faces considerable difficulty in restructuring the initial conception of a pattern, and hence to discover new information in a mental image.

Opposite conclusions on the issue of discovery in imagery are reported by Finke (Finke & Slayton, 1988; Finke, 1990). These authors asked subjects to synthesize simple components into a recognizable object before their inner eye. For example, a capital letter ‘J’ and a letter “D” can form an umbrella. They found that subjects were able to create and discover new unanticipated objects. These kinds of image transformations were called synthesis.

In this thesis it is argued that the differential involvement of analysis and synthesis forms the conciliator between the two opposing conclusions on discovery in imagery. Finke's task does not require analysis, i.e. the initial conception of the components stays intact. In the umbrella example this means that the component structure of each letter ‘J’ and ‘D’ is not violated. Vice versa, the Chambers and Reisberg (1985) task does not require synthesis.

It was hypothesized that if the processes of synthesis and analysis impose different loads on imagery, different effects of paper-and-pencil support can be expected. If the imagery task is easy, as in the Finke’s synthesis task, minor effects are expected. If the imagery task is difficult, sketching, as with Reed’s analysis task is expected to enhance performance.
In two series of experiments this hypothesis was tested. The first series used a Reed-like analysis paradigm (discussed in Chapter 2), the second series used a Finke-like synthesis paradigm (Chapter 3). Both series used expert sketchers as subjects.

For the analysis paradigm configurations were created which consisted of 3 overlapping simple wire-frame components (e.g. square, isosceles triangle and circle). The rules for combining the elements into a pattern facilitated reproduction of a pattern in a sketch. Presentation of the pattern was kept short to ensure that the structure of the pattern was perceived as a combination of simple wire-frame components. The task was to find a part in the pattern, that resulted from the overlap, and hence was not in the perceived structure. Therefore a novel decomposition had to be made before detection. Novel decomposition is identified as a form of analysis, because the initial structuring has to be abandoned in favor of a new one. A condition was composed in which subjects were allowed to sketch and one in which subjects were denied this strategy (imagery only).

A significant increase was found in performance in the sketching condition on discovering the parts which resulted from overlap. The other condition acted on chance-level. Moreover, in a follow-up experiment, it was found that when free paper and pencil was offered, subjects spontaneously started sketching on trials that required restructuring. In this latter experiment, the likelihood of finding the combination of a spontaneous sketch and a correct answer on these analysis trials increased with creativity, as measured with Kunzendorf’s creativity test (Kunzendorf, 1982).

Hence, in this analysis paradigm the surplus of making things visible through sketching was confirmed.

In the synthesis paradigm subjects combined 3 out of 6 possible simple 3D components (like a cube, sphere and cone) into one object. The limited set of 6 components and the fact that each subject got the same subsets of components enabled us to compare between subjects. Again, one half of the subjects was allowed to sketch, the other half wasn’t.

Different synthesis strategies were distinguished in the resulting objects. For example, an object could have been created by simple piling up of components, or by enclosing two component in the third one. It was found that the subjects in the sketch-condition synthesized the elements in similar ways as those in the without-sketch condition. Across their total number of 8 objects the sketch subjects switched between synthesizing strategies as often as their non-sketching counterparts. It was therefore concluded that the synthesis component of the synthesis task yielded no surplus for paper and pencil support.

However, certain aspects of the task seem to benefit from sketching. Often the components were changed in certain qualities with respect to the way they were initially presented and conceived. For example, although a cube was one of the components of the set, it was frequently transformed into a rectangular box. A performance measure resulting from adding up all these kinds of changes was construed. A considerably larger number was found in the sketch condition than in the without-sketch condition. It was hypothesized that these changes occur in the structure of the elements as conceived, and thus are de facto forms of analysis.
This hypothesis can be tested by assuming that subjects, who made more of these analytic transformations in the synthesis task, are likely to have detected more implicit parts in the analysis task. Eleven subjects in the with-sketch condition joined both experiments. The number of analytic transformations in the synthesis task correlated highly significantly with their number of correctly detected parts in the analysis task, supporting the idea that these changes are in fact restructurings.

Additional support for the dissociation of synthesis and analysis processes in the synthesis task comes from creativity ratings. All synthesized objects were rated on creativity by three different judges. On the one hand subjects, who switched between synthesizing strategies more often, received considerable higher ratings on creativity. This effect occurred irrespective from condition (with- or without-sketch). On the other hand, the subjects who performed more analytic transformations according to our changes measure got higher creativity ratings.

Although the discussed results apply only to expert sketchers, in the majority of the experiments they have been compared to novices. Novices performed like experts on synthesis measures. Similar performances were also found on analysis measures in the without-sketch conditions. The only difference between novices and expert sketchers was found on the analysis measures in sketching condition. In the sketch conditions the experts outperformed the novices on the analysis measure.

It was concluded that sketching fulfils a role in supporting analytic transformations, but not in synthetic ones, but that both types of transformations fulfil a role in the creative process. Furthermore, it was concluded that the more expertized and creative the sketcher is, the more he/she will benefit from the externalization.

In Chapter 4 it was illustrated how analytic information from sketches fed an expertized sketcher; the artist Paul Kleijne, with new components for his creative process.

In Chapter 5 it is argued that, since synthetic processing is easy and fast in imagery, computerized idea-creation tools ought not to disturb synthetic processing if they are to support creative processes. Moreover, they can perform a supplementary role to paper and pencil, if they facilitate analytic processing. It was concluded that neither of these two demands are met by current CAD systems; both synthetic and analytic processing are faced with ample difficulty.
SAMEN-
VATTING

Of we ons nu afvragen waarom we soms plotseling achterop een envelop een paar ideeën uitschetsen, of waarom een kunstenaar of ontwerper gewoonlijk een reeks schetsen produceert alvorens hij/zij tot een eindproduct komt, of welke faciliteiten een computer moet bieden wil hij het ontwikkelen van ideeën bevorderen, de achterliggende vraag is eigenlijk waarom ons geestesoog dit soort taken niet alleen afkan.
In het verlengde van deze vraag, ligt de vraag of men voor het geestesoog ontdekkingen kan doen. Deze vraag heet recentelijk de aandacht getrokken van experimenteel psychologen. Hoewel uitvinders deze vraag bevestigend beantwoorden, hebben onderzoekers als Chambers en Reisberg, en Reed en Johnsen hiervoor geen anwijzingen gevonden. Anderen daarentegen, zoals Finke en Slayton, lieten zien dat uitvinden voor het geestesoog wel degelijk mogelijk is.

Deze tegenstrijdige onderzoeksbevindingen kunnen verdiscanteerd worden als men er vanuit gaat dat de onderzoekers onder invloed van hun verschillende onderzoekstaken verschillende typen van ontdekkingen hebben bestudeerd.

Chambers en Reisberg (1985) lieten in hun experimenten zien dat proefpersonen voor hun geestesoog een alternatieve interpretatie van een ambiguë figuur (bijv. eend/konijn) niet konden achterhalen. Vervolgonderzoek duidde niet op een absolute onmogelijkheid, maar liet wel zien dat het voor het geestesoog veranderen van een interpretatie bijzonder moeilijk is. Reed en Johnsen's (1995) resultaten zijn van een gelijke strekking: Herstructurering voor het geestesoog is moeilijker dan herstructurering met behulp van de visuele waarneming. Reed en Johnsen gebruikten een taak waarbij een element in een geheel gevonden moest worden. Zij toonden aan dat het vinden van een element dat een onderdeel vormt van de structurele beschrijving van het geheel (een component) evenzo goed kon met behulp van het geestesoog als met behulp van de visuele waarneming. Het vinden van een deel dat geen onderdeel vormde van de structurele beschrijving van het geheel (een element) was moeilijker voor het geestesoog.

Zowel Chambers en Reisberg (1985), als Reed (1974) gebruikten een onderzoekstaak waarin zowel nieuwe elementen ontdekt als oude componenten van de structurele beschrijving geherinterpreteerd moesten worden. De situaties die problemen opleverden waren die, waarin proefpersonen reeds een bepaalde structurele interpretatie van een patroon hadden en waarin de taak hen vroeg deze interpretatie te veranderen. In deze nieuwe interpretatie kon vervolgens de ongeanticipeerde informatie gevonden worden. Deze vorm van structurele transformatie wordt analyse genoemd.

Uit beide onderzoeken kan geconcludeerd worden dat men moeilijkheden ondervindt met het herstructureren van een initiële interpretatie voor het geestesoog, en dientengevolge problemen heeft met het vinden van de nieuwe informatie die vrijkomt na herstructurering.

Finke (Finke & Slayton, 1988; Finke 1990) echter, rapporteerde contrastende bevindingen over het doen ontdekkingen voor het geestesoog. In zijn experimenten vroeg hij de proefpersonen voor hun geestesoog een object samen te stellen uit verschillende eenvoudige componenten. Een letter "J" en een letter "D" kunnen samen bijvoorbeeld een paraplu vormen. Deze vorm van transformatie wordt synthese genoemd.

In deze dissertatie wordt beargumenteerd dat verschillende bijdrage van synthese en analyse de grondslag vormt voor de verschillende wetenschappelijke antwoorden op de vraag of men voor het geestesoog ontdekkingen kan doen. Finke's taak vergt geen analyse: de initiële structuur van de componenten blijft in tact. Vice versa, Chambers en Reisberg's taak vergt geen synthese.
Als synthese en analyse een verschillend beroep doen op het geestesoog, kan een verschillende meerwaarde van pen-en-papier schetsen verwacht worden. Als de taak die uit gevoerd moet worden relatief makkelijk is voor het geestesoog, zoals dat het geval is bij Finke's synthese taak, dan zullen schetsen weinig meerwaarde hebben. Wanneer echter de taak moeilijk is, zoals bij Reed's analyse taak, dan zal het voorhanden zijn van externalisatie mogelijkheden een duidelijke meerwaarde vormen.

Deze hypothese is in twee series van experimenten getest. De eerste serie gebruikte een Finke-achtige synthese paradigma, de tweede serie een Reed-achtige analyse paradigma. Beide werden uitgevoerd met ervaren schetsers.

Voor de experimenten met de analyse taak werden configuraties gecreëerd die bestonden uit overlappende simpele draad-figuren (bijv. een vierkant, een gelijkbenig driehoek en een cirkel). Ter vergemakkelijking van de reproductie van een configuratie waren de plaatsbepalingen van de draad-figuren binnen een configuratie aan regels gebonden. De presentatietijd van een configuratie was zo kort dat alleen de identiteit van de draad-figuren en hun onderlinge plaatsbepaling gezien konden worden. De taak voor de proefpersoon was nu een element te vinden die ontstaan was door de overlappende draad-figuren, deze bevond zich dientengevolge niet in de waargenomen structuur. Hiervoor moest dus een nieuwe decompositie plaatsvinden. Deze nieuwe decompositie is een vorm van analyse omdat de aanvankelijk waargenomen structuur plaats moet maken voor een nieuwe structuur. Twee condities waren opgenomen in deze experimenten, één waarin de proefpersonen mochten schetsen (de schets conditie), en één waarin zij dat niet mochten (de alleen-geestesoog conditie).


In de experimenten met het synthese paradigma combineerden de proefpersonen drie simpele 3D figuren (als een kubus, bol en kegel) tot een object. Het beperkte aantal van 6 mogelijke 3D figuren en het feit dat alle proefpersonen de zelfde subset van figuren kregen, maakte het mogelijk om tussen proefpersonen te vergelijken. Ook hier mocht één groep proefpersonen schetsen en de ander niet.

Sommige aspecten van de synthese taak bleken echter wel degelijk te profiteren van schetsen. Vaak werden objecten aangetroffen waarin de figuren waren veranderd ten opzichte van hoe ze oorspronkelijk waren aangeboden. Zo kwam het regelmatig voor dat een kubus getransformeerd werd tot een rechthoekige vorm. Het aantal van dergelijke veranderingen dat werd aangetroffen vormde een maat voor analyse binnen de synthese taak. De score op deze maat viel significant hoger uit voor de schets-groep dan voor de niet-schets groep. De hypothese werd geponeerd dat deze veranderingen structurele veranderingen waren, en de facto een vorm van analyse.

Deze hypothese kan getoetst worden als wordt aangenomen dat de proefpersonen die meer van dit soort analytische transformaties toepasten in de synthese taak, waarschijnlijk ook meer impliciete elementen ontdekten in de analyse taak. 11 Proefpersonen hebben in beide experimenten deelgenomen in de schets-conditie. Hun aantal analytische transformaties in de synthese taak correleerde hoog met het aantal door hen correct ontdekte elementen in de analyse taak. Deze hoge correlatie levert ondersteuning voor het idee dat deze transformaties in feite herstructureringen zijn.

Meer onderbouwing voor de dissociatie van synthese en analyse kan worden gevonden in creativiteits beoordelingen van de objecten. Alle synthese objecten werden beoordeeld op creativiteit door drie verschillende beoordeelaars. Enerzijds werden de beoordelingen beter naarmate proefpersonen meer synthese technieken hadden toegepast (onafhankelijk van conditie). Anderzijds kregen die proefpersonen die een hogere score hadden op de analytische transformatie maat ook een hogere creativiteits beoordeling.

Alhoewel de besproken resultaten alleen van toepassing zijn op ervaren schetser, werden zij in het merendeel van de experimenten vergeleken met beginnende schetser. Deze laatsten scoorden vergelijkbaar op synthese maten. Het enige verschil werd aangetroffen op analyse maten in schets condities. In deze condities scoorden de ervaren schetser aanzienlijk beter dan de beginners.

De conclusie luidt dat schetsen een rol speelt bij analytische transformaties en niet bij synthese, maar dat beiden een rol spelen in het creatieve proces. Daarbij geldt dat des te meer ervaren en creatiever de schetser is des te meer hij/zij het schets medium in zijn/haar voordeel kan benutten.

Hoofdstuk 4 laat zien hoe de kunstenaar Paul Kleijne analytische informatie uit zijn schetsen gebruikt als nieuwe componenten voor verdere creaties.

Hoofdstuk 5 beargumenteert dat, als synthese makkelijk is en snel gaat voor het geestesoog, een computer die ondersteuning beoogt bij het creatieve proces dit synthese proces niet moet zou moeten verstoren. Daarbij zouden deze computers een aanvullende rol moeten spelen bij analyse. Aan beide eisen wordt door huidige CAD systemen niet voldaan; zowel synthese en analyse zijn alleen zeer omstandig uitvoerbaar.
CURRICULUM VITAE


DANKWOORD

Ere wie ere toekomt; Cees, ik ben je erg dankbaar voor je nietaflatende begeleiding en motiatie, en voor de vele keren dat je me hebt voorgehouden dat het allemaal toch niet zo erg kon zijn. Je hebt mij sinds 1988 begeleid, en ik hoop dat het promotorschap de kroon op je inspanningen vormt die je verdient en tevens dat in de toekomst verdere vruchtbare samenwerking voor ons is weggelegd. Ralph, jij voert het lijstje van dierbare en toegewijde steun-en-toeverlaten aan; innig dankbaar ben ik je voor jouw warme ondersteuning en de vele bomen die we opgezet hebben over industrieel ontwerpers en het ontwerpen en de verhinderende inzichten die deze mij verschaffen. Ik hoop dat we het nog ver zullen brengen samen. "Frau Doctor Doppel Whopper" dankt ook haar dierbare en trouwe supporters Roel en Rudolf, en dat jullie nog vaak mijn namen mogen zijn en we nog veel samen mogen reizen. Gabi, I want to thank you for being the first among industrial designers and architects to recognize the value of my work for your field of study and for giving me the opportunity to work quietly at your inspirational institute; but most of all I am grateful for having met such a kind and noble person as you are. Hope we keep on seeing each other. Tot mijn trouwe begeleiders reken ik natuurlijk ook Ronald Hamel, erkentelijk als ik hem ben voor het aanbrengen van de AIO-plaats, maar vooral voor het feit dat hij er altijd was wanneer ik hem nodig had. Hier is tevens een woord van dank aan Corrie van der Lelie op zijn plaats, zij heeft mij voortreffelijk en vakkundig geholpen met de omslag van dit proefschrift. Maar zonder Piep en Miep was het allemaal überhaupt nooit gezien gekomen, en ik ben jullie hier dan ook oprecht dankbaar voor. Tot slot wil ik mijn promotor Jim Hennessey bedanken voor het toelaten van het psychologische experiment. En voor allen die zich aangesproken voelen; bedankt voor versterken van mijn volhardingsvermogen; deze kan geen kwaad voor de toekomst.