Sketching in design idea generation meetings
Stellingen behorende bij het proefschrift

Sketching in design idea generation meetings

Door Remko van der Lugt

1. De kwaliteit van het ideegeneratieproces wordt bij brainstormen voornamelijk bepaald door de hoogte van de ideeproduktie, terwijl bij brainschetsen de kwaliteit wordt bepaald door de mate waarin informatie uit eerder gegeneerde ideeën wordt geïntegreerd in nieuwe ideeën (dit proefschrift).

2. Bij experimenten naar ideegeneratiegroepen is de kwaliteit van de resultaten een slechte maatstaf voor de kwaliteit van het ideegeneratieproces. Meer inzicht biedt de structuur van het ideegeneratieproces (dit proefschrift).

3. Het belang dat gehecht wordt aan de schetsvaardigheid ter ondersteuning van de vroege ideevorming (McKim, 1972; Muller, 1997) wordt overschat. Bij ideegeneratiesessies geeft een goede uitleg bij een slechte kwaliteit schets de benodigde betekenis voor de groepsleden. Daarom is het niet zozeer het vermogen om zich uit te kunnen drukken in schetsen dat ontwerpers goed maakt in het toepassen van visuele ideegeneratieterieken. Eerder is het hun vermogen om schetsen te zien als een momentopname van het ideegeneratieproces en ze als zodanig te interpreteren en te gebruiken (mede dit proefschrift).

4. Een niet te verwaarlozen rol van een facilator is die van 'frame coach'. Een frame coach begeleidt de de groepsleden in het genereren van, en spelen met, verschillende kaders waarin een probleem benaderd kan worden (Valkenburg, 2000). Om te kunnen functioneren als frame coach is inhoudelijke kennis van het probleemveld noodzakelijk. (mede dit proefschrift).


6. Creativiteitstechnieken zijn geen ontwerpmethodologische wonderolie. Zij zijn ontwerpmethoden met een specifiek toepassingsgebied, met name gericht op het stimuleren van creativiteit tijdens het conceptueel ontwerpen.

7. Divergeren zonder convergeren is zinloos (e.g. Isaksen, Dorval, & Treffinger, 2000). Het negeren van de convergente fase in het onderzoek naar de effectiviteit van brainstormingsessies limiteert daarom de validiteit van de conclusies die in zulke onderzoek getrokken worden.

8. Groei in welvaart is niet gelijk aan groei in welzijn. Vele maatschappelijke problemen kunnen worden herleid tot het idealiseren van economische groei als het ultieme doel van de samenleving.


10. Sporten is een gezonde verslapping. Maar net als voor andere verslappingen geldt dat excessief gebruik schadelijk is.
Theses

Sketching in design idea generation meetings

By Remko van der Lugt

1. For brainstorming, the quality of the idea generation process is predominantly determined by the height of the idea production. For brainsketching, the quality of the idea generation process is predominantly determined by the extent to which information in earlier ideas is integrated in new ideas.

2. For experiment with idea generation groups, the quality of the results is a poor measure for the quality of the idea generation process. The structure of the idea generation process is more informative.

3. The importance given to the designer's ability to sketch in early idea generation (McKim, 1972, Muller, 1997) is overrated. During idea generation meetings, a good explanation to a poor sketch gives the sketch sufficient meaning for the other group members. It is not so much the ability to express themselves by means of sketches that makes designers especially suitable for graphic idea generation techniques. Rather, it is their ability to regard sketches as snapshots of the idea generation process, and to interpret and use them accordingly.

4. The role of 'frame coach' is indispensable for the facilitator. A frame coach guides the group members in generating and playing with various frames in which a problem can be approached (Valkenburg, 2000). In order to function as a frame coach, the facilitator needs to have knowledge of the problem area.

5. Computer-supported idea generation techniques like 'group decision rooms', obstruct access to the remote areas of the group's external memory. Consequently, the use of these computer systems leads to poorly integrated idea generation.

6. Creative problem solving techniques are not a 'miracle medicine'. They are design methods with a specific area of application, principally aimed at stimulating creativity during conceptual design activity.

7. Diverging without converging is futile (e.g. Isaksen, Dorval, & Treffinger, 2000). The general avoidance of the convergent phases in research of the effectiveness of brainstorming meetings impedes the validity of the conclusions drawn in such research.

8. An increase in prosperity does not necessarily mean an increase in well-being. Many societal problems can be attributed to the idealization of economic growth as the ultimate goal in society.

9. Experiential learning (Kolb, 1984) is often regarded as 'to let the students do all the work'. However, effective application of experiential learning in education requires at least as much effort from the teacher as more traditional ways of teaching do.

10. Exercising is a healthy addiction. Yet, as with other addictions, excessive use is harmful.
Sketching in design idea generation meetings
Sketching in design idea generation meetings

Proefschrift

Ter verkrijging van de graad van doctor
aan de Technische Universiteit Delft,
op gezag van de Rector Magnificus prof. ir. K. F. Wakker,
Voorzitter van het College voor Promoties,
in het openbaar te verdedigen op dinsdag 11 september 2001 om 16.00 uur

door Remko VAN DER LUGT
maritiem ingenieur
geboren te Rotterdam.
Dit proefschrift is goedgekeurd door de promotor:
Prof. dr. ir. J. A. Buijs

Samenstelling promotiecommissie:
Rector Magnificus, voorzitter
Prof. dr. ir. J. A. Buijs, Technische Universiteit Delft, promotor
Prof. dr. G. Goldschmidt, Technion, Israël
Prof. dr. ir. A. W. M. Meijers, Technische Universiteit Delft
Prof. dr. G. J. Puccio, Buffalo State College, State University of New York
Prof. dr. S. A. R. Scrivener, Coventry University, UK
Dr. ir. C. H. Dorst, Technische Universiteit Eindhoven

Dr. ir. C. H. Dorst heeft als begeleider in belangrijke mate aan de totstandkoming van het proefschrift bijgedragen.

ISBN 90-9015014-5

Cover and lay out design by Iris de Graaf

Copyright © Remko van der Lugt
All rights reserved.

Correspondence to: Delft University of Technology, Industrial Design Engineering, Product Innovation and Management, Jaffalaan 9, 2628 BX Delft, The Netherlands.
E-mail: R.vanderlugt@io.tudelft.nl
Preface

What draws a naval architect to start a doctoral research project on the subject of sketching in design idea generation meetings? This question can be answered by describing a journey that started in the final years of my training as a naval architect. As I started the large integrated ship design project that is part of the study (my assignment was to design a stern trawler, which is a large fishing vessel), I was struck by the lack of creativity and conceptual freedom in the taught design method. The conceptual phase of ship design limited itself to selecting a certain number of ships operating in the market that approximately met the requirements for the vessel to be designed. Then, by means of interpolating key design coefficients, the needed coefficients for the new ship could be determined. These coefficients then formed the starting point of a converging iterative cycle, in which the design is refined by determining propulsion and resistance, cargo volume, buoyancy, stability, etc.

No training was given in tackling conceptual design problems; what if there are no ships in the market to provide a starting point for designing? Although ships are one-off products requiring large investments and therefore shipping companies are usually quite reluctant to make conceptual innovations, shouldn’t naval architects at least have the possibility of thinking innovatively? Such questions made me increasingly interested in the conceptual part of the design process. Luckily, the curriculum of the neighboring department of Industrial Design Engineering is very much geared towards teaching students conceptual design. I took a number of elective courses in this department, ranging from courses in management of product development, creative problem-solving and freehand drawing. This resulted in a graduation project in which I applied the learnt skills to generate new concepts for improving the logistical chain of forest products, i.e. paper, from Scandinavia to inland Europe.

By this time I had become so fascinated with the subjects of creativity and innovation that I decided to extend my education by enrolling in a Master’s Program in Studies in Creativity in Buffalo, New York. This program, which was initiated by Alex Osborn, the ‘father of brainstorming’, covers many different facets of the subject of creativity, taking among other things, psychological, philosophical, educational and business perspectives.

On returning to The Netherlands, I joined a small product design agency, which allowed me to apply the gained knowledge in practice, and to experience the practicalities of conceptual design activity. In working together with product designers, I was struck by the differences in the creative group processes described in theory and the creative group design process that I experienced. In creative problem solving methodology, group members are dissuaded from making (positive
or negative) comments on the ideas generated. If anything, they are asked to react to ideas by generating new ideas. In contrast, standing together at the drawing board, we were continuously discussing while making idea sketches. And rather than obstructing the creative process, there was a lot of creative energy in this combined activity of sketching and discussing. Having received thorough training in creative problem solving, I could not help feeling that we were doing something 'wrong', and yet, the activity and the resulting design ideas were marked by a high level of creativity. This perceived conflict between how the creative process should be in theory, and how it was when designing, sparked my interest. I talked to Professor Jan Buijs about this subject, and before I knew it, I had become a Ph.D. student, setting out to increase the applicability of creative problem solving methods for product designers. The principal question that we started out with was: "Wouldn't it be nice to combine the creative potential present in the design meetings at the drawing board and creative problem solving meetings?"

The differences in the working medium used between creative problem solving meetings and informal design meetings swiftly became a central point of inquiry. As mentioned before, designers make extensive use of sketches in creative design activity, but when they feel the need to stimulate their creativity, they organize creative problem solving meetings, which are characterized by lists of written ideas being produced. In the first empirical study I tried out various ways of including sketching in brainstorming meetings. But, rather than providing better creative problem solving techniques for designers, including sketching appeared to break down the brainstorming process. This lead to shifting the research aims, from attempting to develop better applicable creative problem solving techniques for designers, towards a more theory-oriented aim of gaining a more thorough understanding of the differences in the creative group process, when sketching or writing is used as a working medium.

The results of the empirical studies lead me to suggest that when sketching is used in idea generation activity, the interpretation and building on earlier ideas is central to the idea generation process, while for regular brainstorming, with written language as a working medium, the production of a large number of ideas is central. This lead to suggesting a set of alternative guidelines.

Doctoral students tend to go through a rather predictable series of phases, not unlike product innovation projects (e.g. Nolan, 1987) which range from excitement and hunger for knowledge in the beginning of the project, through darker times (boy, this is taking a long time ... will I ever be able to finish this?), with increasing enthusiasm when finally, the end of the project is coming close (hey, I am actually good at this), and ending with physical exhaustion in the last weeks of finalizing the thesis. I definitely experienced this project as such a journey. There are quite a few people who have helped me along the way, and without whom it would not have been possible to complete this journey.
Of course, there are the people who have provided essential support in the actual work. After luring me into this research project, Jan Buijs proved to be a very supportive supervisor, who as well as providing me with great conditions for developing myself as a researcher, was also very supportive as I went through some major life changes, of which clearly becoming a father has been the most momentous. When I was desperately trying to get out of the trough of the research project, about halfway through, Kees Dorst joined in, and helped structuring my research efforts. Kees has been a great mentor and coach, and I wonder if I would have made it out without him. Then, when I started writing the thesis Peter Lloyd joined the team. By his critical attitude to research he has helped improve the thesis tremendously. It was not always fun to discuss his long lists of comments at meetings. Oftentimes I would disagree strongly with his comments when discussing a chapter. But then, a few weeks after the meeting, I would read through the chapter again and have to admit that he had been right all along.

A number of people have provided substantial support for which I am grateful. Gijs Verrest and Claartje Vorstman were willing to facilitate the creative problem solving meetings in the second experiment. Anne van der Graaf, as a research student spent many hours behind the video screen to determine whether context indicators for ideas were present or not. And Jan-Paul Teunissen and Marja Houtman helped develop the design task used in the second study. Jan-Paul, Anne and Marja also constructed the link matrices needed for determining the inter-rater agreement. Dominique Afzal-Woodward corrected my use of the English language and Iris de Graaf, with her graphic design skills, made the thesis look as good as it does.

I am very thankful to Niels Moes, for introducing me to running during lunch breaks. We spent many hours running together in the beautiful surroundings of Delft. The long runs in preparation of a marathon proved to provide excellent moments of incubation, which lead to many research ideas that I would probably not have been able to conceive while behind a computer screen.

And in last phase of this journey my dear ‘paranymphs’, Tanya Schwartz and Arjen de Boer, will help me through the final leg. Tanya, as well as being a great sister in-law, you have been such a wonderful example for me. You showed me how it was possible to finish a Ph.D. project while keeping sane. And Arjen, you have been a great friend, I have thoroughly enjoyed the many hours swimming and cycling that we have spent together, and I hope many more will follow.

In the past five years, since I started my Ph.D. research project, many changes have happened in my life. My long-distance girlfriend in the United States moved in with me...with her two cats, Love and Mo! Soon Becky and I got married. A few months after that, our son Sam was born. And, recently, our daughter Sarah came into our lives. These family changes rightfully forced me to seek a balance between work on my thesis and devoting time to the family. Sam and Sarah, I would like to
thank you for being in my life. Each day, you make me aware that there are much more important things in life than finishing a dissertation.

Without my parents, it would have not been possible for me to finish this project and build a family at the same time. As well as your moral support, and the time you spent taking care of Sam and Sarah when we needed the space, you provided us with the nest in which we could build our family.

Becky, thank you so much for all the support that you have given me, and especially for making sure that I did not 'disappear' into my project. Many evenings you would pull me back out of my world of thoughts and worries about my dissertation and bring me back into the warmth of family life. Becky, I love building a family with you, and I think that we are doing a damn good job! The times of hardship while we lived at opposite sides of the Atlantic Ocean and would see each other for only a few weeks a year have been well rewarded by your presence.

Remko van der Lugt

Delft, July 2001
# Table of contents

**Preface**

<table>
<thead>
<tr>
<th>1</th>
<th>Creative Problem Solving meetings in product design: an introduction</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Introduction</td>
<td>15</td>
</tr>
<tr>
<td>1.2</td>
<td>Creative problem solving</td>
<td>16</td>
</tr>
<tr>
<td>1.2.1</td>
<td>Introduction</td>
<td>16</td>
</tr>
<tr>
<td>1.2.2</td>
<td>A brief history of the creative problem solving method</td>
<td>17</td>
</tr>
<tr>
<td>1.2.3</td>
<td>Elements of the creative problem solving method</td>
<td>17</td>
</tr>
<tr>
<td>1.3</td>
<td>Studies on the effectiveness of the creative problem solving method</td>
<td>21</td>
</tr>
<tr>
<td>1.3.1</td>
<td>Group brainstorming versus individual brainstorming</td>
<td>21</td>
</tr>
<tr>
<td>1.3.2</td>
<td>Brainstorming groups versus conventional meetings</td>
<td>22</td>
</tr>
<tr>
<td>1.3.3</td>
<td>Brainstorming groups in context</td>
<td>22</td>
</tr>
<tr>
<td>1.4</td>
<td>Creative Problem Solving as a design method: A domain-specific approach</td>
<td>27</td>
</tr>
<tr>
<td>1.4.1</td>
<td>The case for a domain-specific approach</td>
<td>27</td>
</tr>
<tr>
<td>1.4.2</td>
<td>Creative Problem Solving as a design method</td>
<td>28</td>
</tr>
<tr>
<td>1.4.3</td>
<td>A detected need for visual expression during idea generation</td>
<td>29</td>
</tr>
<tr>
<td>1.5</td>
<td>Research issues</td>
<td>34</td>
</tr>
<tr>
<td>1.5.1</td>
<td>Limiting the scope of research</td>
<td>34</td>
</tr>
<tr>
<td>1.5.2</td>
<td>Research questions</td>
<td>35</td>
</tr>
<tr>
<td>1.5.3</td>
<td>Introduction to the remainder of this thesis</td>
<td>35</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2</th>
<th>The role of sketching in creative design groups</th>
<th>39</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Introduction</td>
<td>39</td>
</tr>
<tr>
<td>2.2</td>
<td>The role of sketching in group design activity</td>
<td>39</td>
</tr>
<tr>
<td>2.2.1</td>
<td>A basic categorization of design sketches</td>
<td>39</td>
</tr>
<tr>
<td>2.2.2</td>
<td>The thinking sketch</td>
<td>40</td>
</tr>
<tr>
<td>2.2.3</td>
<td>The talking sketch</td>
<td>41</td>
</tr>
<tr>
<td>2.2.4</td>
<td>The storing sketch</td>
<td>41</td>
</tr>
<tr>
<td>2.3</td>
<td>Potential functions of sketching in idea generation meetings</td>
<td>49</td>
</tr>
</tbody>
</table>
3 Research approach: Linkography

3.1 Introduction

3.2 A process perspective to examine idea generation meetings
   3.2.1 The dominant outcomes approach in research on the creative process
   3.2.2 The rationale for taking a process perspective
   3.2.3 Linking as a quality measure for the idea generation process

3.3 Linkography
   3.3.1 Introduction
   3.3.2 Methods that analyze the structure of design processes
   3.3.3 Linkography as proposed by Goldschmidt

3.4 Adapting linkography
   3.4.1 An idea generation meeting in product design
   3.4.2 Adapting linkography for analyzing idea generation activity

3.5 Applying linkography
   3.5.1 Constructing a link matrix
   3.5.2 Link density
   3.5.3 Self-link index
   3.5.4 Link type indices

3.6 Reliability of linkography
   3.6.1 Introduction
   3.6.2 Inter rater agreement
   3.6.3 The group members as link raters?

3.7 Summary

4 Exploring the compatibility of the processes of brainstorming and idea sketching

4.1 Introduction

4.2 Experimental meetings with graphic variations of the brainstorming technique
   4.2.1 Introduction
   4.2.2 Experimental set-up
   4.2.3 The graphic variations to brainstorming applied

4.3 Applying linkography to the experimental meetings
   4.3.1 Constructing link matrices
   4.3.2 Inter-rater agreement
4.4 Discussion of results

4.4.1 Results
4.4.2 Graphic facilitator (meeting A)
4.4.3 Visual brainstorming (meeting B)
4.4.4 Brainstorming with added sketches (meeting C)

4.5 Conclusion

5 Comparing a graphic and a sentential technique for generating ideas

5.1 Introduction

5.2 Experiment design

5.2.1 A paired comparison approach
5.2.2 Two representatives of idea generation techniques
5.2.3 The idea generation task
5.2.4 Group composition
5.2.5 Meeting plan
5.2.6 Experimental set-up

5.3 Constructing link matrices

5.3.1 Introduction
5.3.2 Reliability

5.4 Linking in terms of interaction with external memory

5.4.1 Introduction
5.4.2 External memory according to Newell & Simon
5.4.3 Interaction with external memory in design groups
5.4.4 An example of interaction with external memory
5.4.5 Link densities for the four external memory types

5.5 Results

5.5.1 General results
5.5.2 Number of ideas
5.5.3 Link density
5.5.4 Self-Link Index
5.5.5 Link type indices
5.5.6 Interaction with the four parts of the group's external memory

5.6 Discussion: Typical idea generation processes for brainstorming and brainsketching

5.6.1 Introduction
5.6.2 A typical example of the brainsketching idea generation process
5.6.3 A typical example of the brainstorming linking process
5.6.4 Different purposes of graphic and sentential idea generation techniques
6 Conclusions and further developments:
Sketching in design idea generation meetings

6.1 Summarizing conclusions

6.1.1 Introduction

6.1.2 Research question 1: How do various ways of including sketching in idea generation meetings influence the idea generation process?

6.1.3 Research question 2: What are the differences in the structure of idea generation processes, when sketching or written language is used as a working medium?

6.1.4 Research question 3: How can idea generation processes be described in such a way that differences in these processes can be analyzed, in order to answer the questions regarding the role of sketching in idea generation meetings?

6.2 How including sketching in idea generation meetings affects the idea generation process

6.2.1 Introduction

6.2.2 Function 1: Sketching supports an individual re-interpretive cycle.

6.2.3 Function 2: Sketching invites re-interpretation of each other's ideas.

6.2.4 Function 3: Sketching enhances the accessibility of earlier ideas.

6.2.5 Functions of sketching in idea generation meetings

6.3 Differences in structure of the sentential and graphic idea generation processes

6.3.1 Differences in activities in graphic and sentential idea generation

6.3.2 Reconsidering the divergent thinking guidelines when sketching is used

6.3.3 Four alternative guidelines for graphic idea generation techniques

6.4 The role of context indicators in linkography

6.4.1 Introduction

6.4.2 Types of context indicators

6.4.3 Ratio of links supported by context indicators

6.5 Further speculations on the brainsketching technique

6.5.1 Stimulating group reflection

6.5.2 Applicability of brainsketching for participants without a design background

6.6 Recommendations for further research
Glossary of introduced terms ........................................ 191
Summary ............................................................................ 193
Samenvatting ................................................................. 199
References ........................................................................ 207
Curriculum Vitae ............................................................ 215
Product design has shifted from predominantly individual activity towards predominantly team-oriented activity. Valkenburg (2000) provides an explanation for this notion, related to the changing nature of product design. According to her, there is an increased complexity in product design projects, product design tasks, and product design communication. Companies have turned towards teamwork in order to cope with these new challenges in designing. According to Valkenburg: "Many companies seek competitive advantage and a better integration of acquired knowledge by using teamwork. Only teamwork enables them to cope with the required efficiency and to deal with the increased number of parallel activities in new product development" (p.13).

As product design has become increasingly team oriented, creative problem solving has become a popular method for structuring design team meetings when ideas need to be generated.

In creative problem solving meetings, the primary mode of expressing ideas is written language; the facilitator of the meeting jots down ideas on a flipchart. Perhaps this is because the creative problem solving method has become popular in a business context as a managerial tool, and in this domain, words are the primary mode of expression.

Design researchers often connect the activity of sketching to creativity in design (e.g. Fish & Scrivener, 1990; Goldschmidt, 1991; Schön & Wiggins, 1992; Goel, 1995). Designers tend to make extensive use of sketching when generating design ideas. However, when they are engaged in creative problem solving meetings, they revert to written words as a primary means of recording ideas. It is likely that this is due to written language being the working medium in the general creative problem solving method.

This could imply one of two things: either the focus of the use of words is a structural part of the creative problem solving method, which would imply that, when generating ideas, shifting the mode of expression from sketches towards words stimulates creativity in design groups. Or, creative problem solving has been incorporated as a design method without a critical review of the mode of expression used. If this is the case, adjusting the method to the specific conditions of the domain may enhance its applicability to this domain.

Before being able to make inferences regarding the value of either mode of expressing ideas within creative problem solving meetings in product design, an
understanding needs to be attained of the differences in the idea generation processes between creative problem solving meetings that use sketching and creative problem solving meetings that use words as a primary means for notation of ideas. This provides the primary objective of this research. Only after the characteristics of each idea generation process are appreciated can guidelines be constructed regarding their applicability. This is a secondary objective, which will be dealt with in the final chapter of this thesis.

This introductory chapter starts out with a short introduction to the creative problem solving method (section 1.2). A brief review of research done on the effectiveness of brainstorming meetings is provided in section 1.3. Then, a domain-specific perspective, rather than a generalist perspective, for furthering the creative problem solving method is proposed (section 1.4). The domain considered in this thesis is product design, which directs the inquiry towards the role of sketching in idea generation meetings. The inquiry is structured by means of three research questions presented in section 1.5. In this section, a brief introduction to the remainder of this thesis is provided as well, in order to supply the reader with an outline of the research project.

1.2 Creative problem solving

1.2.1 Introduction

The working definition of creative problem solving used in this dissertation encompasses a variety of available methods. We use the following definition: "Creative problem solving is the general name for all methods in which problems are solved by groups using techniques for structuring and stimulating creativity". This includes many of the efforts made to stimulate creativity in relation to problem solving. Some of the most widely known methods are: Synectics (Gordon, 1960), the Buffalo Creative Problem Solving method (Isaksen, Dorval & Treffinger, 1994), and De Bono’s Lateral Thinking method (see De Bono, 1970, for the original publication on lateral thinking, and De Bono, 1992, for an overview of Lateral Thinking techniques). Because the Buffalo Creative Problem Solving method is supported by a body of research (e.g. Parnes, 1987; Rose & Lin, 1984; Meadow, Parnes & Reese, 1959), and because the creative problem course at the Delft School of Industrial Design Engineering is largely based on this method (Buijs & Nauta, 1991), the Buffalo creative problem solving method is used as a basic framework in this research project. Most other creative problem solving methods are largely based on similar underlying principles. To provide some background on the method, a brief overview of some of the principal historical states of the creative problem solving method is provided, followed by an introduction to the key terms.
A brief history of the creative problem solving method

The Buffalo (New York)-based efforts to enhance creativity started with Alex Osborn’s applications of brainstorming in an advertising agency (Osborn, 1942). Osborn developed brainstorming as an idea generation tool. He realized that a technique for generating ideas would, by itself, not be sufficient as a method for solving novel problems. He developed a method that also encompassed phases for problem analysis, and for idea selection and development. This was the original version of a method called Creative Problem Solving (Osborn, 1953).

Since its origination, the creative problem solving method has been subject to many changes. The openly eclectic nature of the approach allowed for a continuous inclusion of new insights into the method. Sid Parnes (1992), Osborn’s successor as director of the Center for Studies in Creativity in Buffalo, NY, mentions in respect to this:

Over the years, since first encountering Alex Osborn’s program (1953), I have tried to establish an eclectic approach to the development of the most comprehensive program possible for nurturing creative behavior. Starting with Osborn’s well-known model, I have tried to synthesize theories and programs we could uncover, as well as many new approaches that were developed concurrently over the past four decades. (p. 143)

In his seminal description, Osborn describes creative problem solving as a process of seven stages: 1) Orientation; 2) Preparation; 3) Analysis; 4) Hypothesis; 5) Incubation; 6) Synthesis; and, 7) Verification. The model strongly resembles Wallas’ famous description of the creative process, which includes the stages of preparation, incubation, illumination, and verification (Wallas, 1926). He then condensed the creative problem solving process into three more comprehensive procedures: fact-finding, idea-finding, and solution-finding (Osborn, 1963). Some years later, together with Parnes, Osborn developed a five-stage model (Parnes, 1967), which is still widely used by creative problem solving practitioners. This model is also referred to as ‘Osborn-Parnes creative problem solving’(figure 1.1):

In this model, two stages are added to the initial three stages of Osborn’s model. After fact-finding, a stage of problem-finding is included, with the objective of generating problem statements after the key information surrounding the problem is identified. A stage of acceptance-finding is included after the solution-finding stage, in order not only to identify solutions, but also to strengthen them.
Scott Isaksen, in his turn Parnes' successor as director of the Center for Studies in Creativity, together with Don Treffinger, included a step of 'mess-finding', which was aimed at clarifying the objectives of the creative problem solving efforts (Isaksen & Treffinger, 1985). Later, they reacted to what Isaksen called, "the gravity feed view of the creative problem solving model" (Isaksen et al. 1994, p. 57), meaning that the creative problem solving method was based on a step-by-step prescriptive model, in which one starts at step one at the top of the model and continues downward until the final step at the bottom of the model has been taken. According to Isaksen et al (2000):

...there was often more emphasis on using every step than on the intended outcomes or the appropriate process steps to help attain them. As a result, it was not uncommon to have marathon sessions lasting for many hours until fatigue set in for everyone. (p.41)

The efforts that were made to achieve a more flexible process led towards the contemporary 'descriptive model' of creative problem solving (Isaksen et al, 1994). In this model, the task requirements determine which phase is most appropriate to be in at any time of the creative problem solving process. Figure 1.2 shows a graphic depiction of this model.

The descriptive creative problem solving model consists of three main components that are subdivided into, in total, seven stages. The meta-component of task appraisal and process planning is intended to guide the process towards the most appropriate activity at any particular time. When engaging in creative problem solving activity, one starts with task appraisal to determine the best component to start with. Upon finishing with the component, one revisits task appraisal to determine in which direction the problem solving process should next be headed.
Elements of the creative problem solving method

The three main components of the contemporary version of the creative problem solving method are briefly described below (based on Isaksen et al., 1994).

- **Understanding the Problem** involves the stages of mess-finding, data-finding, and problem-finding. The main emphasis in this component is to clarify the focus on the desired results. The Understanding the Problem component helps identify gaps between the current reality and images of the desired future state. In mess-finding, the goal is to conduct a general search to identify challenges and opportunities present in a task situation. In data-finding, the goal is to increase understanding of the task situation by gathering a wide range of related information. In problem finding, the goal is to identify specific directions for generating ideas.

- **Generating Ideas** contains only one stage, namely, idea-finding. This component is concerned with generating many, varied, and unusual ideas to respond to a question that has already been formulated. Such a clear and focused question may be the result of a previous step within the 'Finding the Problem' component, but it may also have a different origin. The idea-finding stage also includes an initial round of idea selection.

- **Planning for Action** involves the stages of solution-finding and acceptance-finding. This component aims to transform ideas into action. In solution finding, the goal is to evaluate and strengthen promising ideas. In acceptance finding, the goal is to convert solutions into specific actions that need to be taken for implementation.

The main underlying principle in creative problem solving is alternating divergent and convergent phases in the problem solving process. Each stage consists of at least one combination of a divergent and a convergent phase. In a divergent phase, group members generate options while following the four well-known guidelines for brainstorming (Osborn, 1953). In the subsequent convergent phase, the options are screened and evaluated. Combinations of divergent- and convergent phases are often modeled as a diamond or lozenge. The idea behind this is that a number of variations—or options are generated, followed by a phase of careful reduction of options, by means of selection, combination and evaluation. Some argue that these divergent and convergent activities are interrelated to such an extent, that a combination of a divergent step and a convergent step constitute a single phase (e.g. Buijs, 1987).

Below, the four guidelines for divergent activity are briefly described:

1. **Deferring judgment:** Postpone evaluating options until a full range of options is generated. Analysis and evaluation are important in creative thinking, but they also obstruct the process of generating ideas.
2. **Striving for quantity**: Also known as 'quantity breeds quality'. The greater the number of options generated, the higher the chances of discovering options that are novel and useful. Parnes (1961) found that while brainstorming, the best (most unique, most valuable) options are to be found among the later 33% of the generated options.

3. **Freewheeling**: This rule emphasizes recognizing the value of every option that comes to mind. Ideas that might seem to be wild, unrelated or useless can function as springboards for other options. They are a source for unique viewpoints.

4. **Seeking combinations**: This guideline is also known as 'building on other ideas' or 'hitchhiking'. By looking for combinations, more novel and useful ideas are found. It also means that most ideas can be improved upon by modifying their attributes (VanGundy, 1988).

Convergent activities are also structured by four general guidelines (Isaksen, Dorval & Treffinger, 1994). The main objective of these guidelines is to provide for a constructive type of evaluation, rather than the more common practice of 'killing' ideas until the good ones are left. The four convergent guidelines proposed by Isaksen et al are:

1. **Use affirmative judgment**. This is the principal convergent guideline, which suggests keeping a positive approach to evaluating options. This guideline recommends looking at ideas in terms of what may need improvement, rather than looking for reasons why options are not feasible.

2. **Be deliberate**. Taking a systematic approach may help avoid conflict in group decision making, and it helps to look at ideas with a clear and appropriate set of criteria.

3. **Consider novelty**. This guideline specifically addresses the tendency to 'kill off novel ideas' because they take more effort to implement.

4. **Stay on course**. This guideline emphasizes the need to keep in mind the original purpose of the problem solving efforts.

A typical creative problem solving meeting consists of five to seven group members and is directed by a facilitator who also records the options generated. Osborn (1953) initially suggested groups of about ten participants. In later years, this number has been cut down, mainly due to small-group research insights. Research in this field identified a negative effect on productivity when group size increases (Diehl & Stroebe, 1987).

In addition to the role of group member, there are two other roles in creative problem solving meetings, the role of the facilitator and the role of the so-called problem owner or client. The role of facilitator is to guide the process, without engaging in the content of the task at hand. He/she does not generate or select options him/herself, but guides the group members in applying various tools for
stimulating creativity. In management consulting, this role is identified as 'process consultation' (see Schein, 1969; 1987; Buijs, 1987). The client or problem owner is primarily responsible for implementing the results and is therefore the most suitable person for making critical decisions about the content. Ideally there is one client. In the context of product design, often the meeting consists of a design team, in which all the team members have a stake in implementing the meeting results. This is called 'shared clientship', which can make the converging process more complicated.

**Studies on the effectiveness of the creative problem solving method.**

**1.3 Group brainstorming versus individual brainstorming**

Research on the effectiveness of creative problem solving has mostly focused on its central mechanism, the brainstorming technique. Most of this research has compared groups versus individual brainstorming activity. Since the introduction of brainstorming, many studies have been undertaken to verify its claims. These research efforts have mainly focused on Osborn's (1953) early claim that group brainstorming can double the idea production compared to groups in which the members generate their ideas individually and combine them afterwards. The latter are usually referred to as 'nominal groups'.

The first study on 'real' brainstorming groups versus nominal groups was conducted by Taylor, Berry, & Block (1958). Taylor et al compared 12 groups of four college students generating ideas jointly with 48 students generating ideas individually. In the latter condition, the ideas of four of the subjects were combined as if they were a group. The results of this study were that; (1) Nominal groups produced significantly more ideas than the real brainstorming groups; (2) the nominal groups produced a higher number of unique ideas, and; (3) the nominal groups scored better on performance, measured by assessing the 'feasibility', 'effectiveness', and 'generality' of the ideas generated. They conclude that: "group participation when using brainstorming inhibits creative thinking" (p. 43). The results of the research on groups versus individuals using brainstorming have been replicated many times (most recently by Nijstad, 2000; see Diehl & Stroebe, 1987, for an overview of 22 studies).

Apparently, researchers like to present this claim in their articles, so that they can falsify it. By rejecting this single claim they also reject the entire brainstorming approach. However, even though Osborn made this claim in the first version of 'Applied Imagination', in later versions he made no such assertions. In a review of brainstorming research, Sutton & Hargadon (1996) describe their investigations regarding such a claim in the various versions of Osborn's 'Applied Imagination' in a footnote:
Many articles on productivity loss present this claim from pages 228 and 229 of Osborn's 1957 edition, apparently to create a contrast with evidence that people in face-to-face brainstorming groups actually generate fewer ideas than when brainstorming alone. Mullen, Johnson, & Salas (1991) and Diehl and Stroebe (1991) both referred to it in their opening paragraphs. Stroebe and Diehl's (1994: 272) review stated, "Osborn claimed that adherence to these rules would more than double the ideas of the group members." Our reading of the three editions of Applied Imagination indicates, however, that this claim was only made in the 1957 edition. The 1963 edition contains no claims that group brainstorming is superior to generating ideas alone. Osborn (1963: 152) only stated that "a brainstorming session, properly conducted, can produce more good ideas than a conventional conference and in less time," which is supported by a modest body of research comparing meetings that follow brainstorming rules with meetings that do not (McGrath, 1984).

The only direct statement we can find in this edition about individual versus group productivity is that "Despite the many virtues of group brainstorming, individual ideation is usually more usable, and can be just as productive" (Osborn, 1963: 191). Many authors repeat Osborn's claim of increased individual productivity in brainstorming sessions, but we can find no published paper recognizing that this claim was abandoned by 1963. Thus many studies and reviews are presented as if they are debunking Osborn's claim, even though he abandoned it long before nearly all of this research was conducted. (p. 686)

The problem with the studies on individual versus group brainstorming is that they do not address some of the most relevant issues at stake. As mentioned in the introduction of this chapter, the workplace has become predominantly team oriented in order to be able to deal with increasingly complex tasks. See figure 1.3 for a graphic overview of the increased complexity of product design projects in the past century.

![Figure 1.3: The increased complexity of product design projects (from Valkenburg, 2000)](image_url)
According to Valkenburg (2000), the increased complexity of product design projects requires integration of knowledge from various domains into the products, such as software, electronics, and human interface factors. This demands a multidisciplinary team approach—rather than an individualist approach—to product development, in order for specialists from the various domains to successfully harmonize and apply each other's contribution.

Research on the use of creative problem solving and brainstorming needs to be regarded in the light of the actuality that multidisciplinary teamwork has become the norm in product development. Then, the question of whether group brainstorming outperforms individual brainstorming activity is less interesting. As brainstorming or creative problem solving meetings are used as a tool to improve team performance, it is more useful to compare groups that use creative problem solving with groups that are involved in conventional meetings.

**Brainstorming groups versus conventional meetings**

The empirical research that compares brainstorming groups to conventional group formats is less widespread. Even though most of the following studies are dated, they are still mentioned in the current literature (e.g. Brophy, 1998). Few recent replications of such research are found.

Meadow, Parnes, & Reese (1959) compared the quality of the ideas produced by brainstorming groups with the ideas produced by groups that were instructed to look for high quality ideas. Four groups of eight college students, trained in creative problem solving generated ideas for two problems. One problem was ‘how many uses can you think of for a broom?’, and the other problem was ‘how many uses can you think of for a clothes hanger?’. Two groups first used brainstorming, followed by critical group discussion. The other two groups first applied the critical group discussion guidelines, followed by brainstorming. Quality of ideas was operationalized by combining scores for ‘uniqueness’ and ‘value’. The results of this study show that the brainstorming groups generated more ‘good’ ideas than the non-brainstorming groups.

Weisskopf-Joelsen & Eliseo (1961) studied six groups of seven college students. Three groups followed the guidelines for brainstorming. The other three groups were instructed to emphasize quality and to strive for good, practical ideas. The tasks for both of these groups involved coming up with attractive brand names for a cigar, a deodorant, and an automobile. Judges evaluated the ‘attractiveness’ of the ideas, as a measure of idea quality. The results of this study indicate that the brainstorming groups produced a significantly larger number of ideas. However, the average quality of the ideas in the conventional condition was higher than for the brainstorming condition. This was accounted for, according to the researchers,
by the fact that the brainstorming groups produced a higher number of low quality ideas. The number of high quality ideas produced was about equal for both conditions.

Bouchard (1969) also used this average quality of ideas variable in his comparison of brainstorming groups with 'critical problem solving' groups. He also considered the number of good ideas generated. His subjects were college students who worked on two different tasks, one was a 'fantasy' problem, and the other was a 'realistic' problem. Idea quality was operationalized for the fantasy problem by using a 'practicality-importance' criterion, and for the realistic problem, quality was operationalized by an 'effectiveness' criterion. The results of this study indicated that group brainstorming outperformed critical problem solving for the total number of ideas and the total number of 'good' ideas, but not for the average quality of ideas. The latter effect was explained previously in the Weisskopf-Joelsen & Eliseo (1961) study.

More recently, in reaction to these controlled experiments with college subjects, Ekvall & Parnes (1989) conducted an experiment in which they attempted to simulate a more realistic situation. In this study, the researchers compared four creative problem solving methods, 1) brainstorming, 2) brainstorming combined with analogy thinking, 3) morphological analysis, and, 4) 'creative group leadership' (Maier, 1963). Leaderless group work was used as a control condition. Participants were thirty professional engineers, who were sub-divided into five groups. In this three-day experiment each group received thorough training in one of the problem solving methods, before working on the experimental tasks. The problems used were realistic and appropriate for the product development engineers, for instance one of the problems consisted of designing a traveling bed for small children. The groups were asked to select a solution. The quality of these solutions was rated by a group of independent judges in terms of usefulness, originality, and elegance. Results indicated that brainstorming resulted in slightly better solutions than the leaderless group discussion, but brainstorming combined with analogy outperformed all the other methods. In discussing the results of their study Ekvall & Parnes comment:

*Brainstorming seems to be a good method of producing many ideas, some of which might contain the 'germ' of a new concept. But in order to use this potential, more must be done than is included in the Brainstorming 'listmaking' procedure. The 'germs' should be used as metaphors for further thinking towards a workable solution if Brainstorming principles are to give good solutions to more complicated problems than, for example, finding a name for a new product or ways of attracting more members to an association. There must come a phase of elaboration and development between idea-production and idea-evaluation which is not considered in experiments we have uncovered.* (pp. 138-139)
Consequently, they provide the following explanation for the superiority of the brainstorming plus analogy condition: "... catching a good analogy led to directed elaboration and development towards a solution..." (p.139). The research done by Ekvall & Parnes suggests that it is not very useful to study the effectiveness of the brainstorming technique by itself. The brainstorming technique is part of a more extended method for creative problem solving, which includes phases of investigating the problem and idea development.

**Brainstorming groups in context**

One line of research that stresses the context in which creative problem solving meetings function is an extensive case-study by Sutton & Hargadon (1996). They performed an in-depth study of the functions of brainstorming groups at IDEO, the largest product design consulting firm in the United States (and the world) (see Kelley & Littman, 2001, for an overview of IDEO's approach to product innovation). Following a grounded theory research approach, they used a variety of methods for data collection, such as observations, interviews, a survey, and informal discussions.

The survey was meant to investigate the extent to which brainstorming groups are applied at IDEO. They found that the design agency makes extensive use of brainstorming meetings: IDEO designers participating in the survey (n=37) reported that in the last year they attended between 4 and 80 brainstorming meetings (mean=24).

Brainstorming meetings at IDEO largely follow the creative problem solving method as described in section 1.2. However, the "strive for quantity" guideline is omitted. Instead, the "building on other ideas" is stressed. According to Sutton & Hargadon, these meetings differ from most experimental brainstorming meetings because the participants have: "(1) past and future task interdependence, (2) past and future social relationships, (3) a use for the ideas, (4) pertinent technical expertise, (5) complementary skills, (6) expertise in doing brainstorming, and (7) expertise in leading brainstorming" (p.894).

Sutton & Hargadon uncovered a set of consequences of brainstorming meetings within the context of the product design workplace. They argue that these consequences may be much more important than the dependent variables used in most experimental research: the quality and quantity of ideas generated. Even though this case study appears to have a positive bias—the researchers are out to disqualify the results from experimental brainstorming research by focusing on the benefits of brainstorming meetings within the context of a real company—and granted that some of the uncovered consequences can be regarded as rather trivial, this research still provides some insightful implications. There may be strong added functions of brainstorming meetings when regarded within their context of use, that stretch beyond the quantity and quality of ideas generated, at least within the field
of product design. Sutton & Hargadon reported evidence for the following six consequences of brainstorming meetings at IDEO:

1. **Supporting the organizational memory of design solutions.** According to the researchers, brainstorms add new knowledge to 'IDEO's memory.' Brainstorming meetings at IDEO almost always begin with providing the participant with knowledge about the product, which may cover the clients existing product and competing products. Brainstorming meetings are also ways of dispersing knowledge across the firm, as usually participants from a variety of backgrounds partake in such meetings. They take the newly gained knowledge back to their workplace. Brainstorming meetings also provide a forum for retrieving and using existing design solutions.

2. **Providing skill variety.** The company considers itself to be specialist in the design process, rather than in a specific task. But, even though this process specialist approach of the company suggests that work at IDEO involves many skills, designers often spend large portions of time on a single task. Brainstorming meetings are regarded as 'vacations', in which designers can exercise their multitude of skills.

3. **Supporting an 'attitude of wisdom' (Acting with knowledge while simultaneously doubting what one knows).** Organizing brainstorming meeting is a means of inviting in opinions and knowledge of other designers: it allows designers to be fallible. At the same time these meetings allow designers to use their expertise while giving help to others.

4. **Creating a status auction.** Displaying specific knowledge and skills in brainstorming meetings provides designers with a means to increase their status in an organization where there is little formal hierarchy. Designers acquire status as being particularly good brainstormers or facilitators.

5. **Impressing clients.** Next to the quality of the product proposals presented to the client, brainstorming meetings provide an additional way to impress the clients, namely, by showing the firm's creative capabilities. Brainstorming meetings are an efficient way for clients to explain their problem and to gather new ideas from the designers. Training the clients in brainstorming principles (by inviting them in) provides them with a positive attitude towards ideas.

6. **Providing income.** Brainstorming meetings are an additional income source for the firm. Some clients hire IDEO solely for conducting brainstorming meetings.
Creative Problem Solving as a design method: a domain-specific approach

The case for a domain-specific approach

Creative problem solving methods have been considered to have a broad, if not unlimited, range of applications. In the third revised edition of his monograph 'Applied Imagination', Osborn (1963) claims the versatility of the creative problem solving method. He states:

Group brainstorming has been effectively used in many fields of endeavor, including social service, traffic problems, civic affairs, federal affairs, military affairs, hospitals, churches, education, broadcasting, retailing, marketing, promotion, product design, packaging, personnel problems, safety, cost-cutting, transportation, accounting, engineering and journalism. (p.160)

Parnes (1992) describes creative problem solving as a general system, suggesting universal applicability, and Isaksen, Dorval, & Treffinger (1994) define creative problem solving as a "...broadly applicable process that provides an organizing framework for specific tools that help you design and develop new and useful outcomes. We see creative problem solving as a process framework which functions as an organizing system" (p.31). They too stress the broad applicability of the method.

In its fifty years of development, creative problem solving has developed into a universal method for stimulating creativity. We suspect that this striving for general applicability in the field provides an obstacle for further development. Like the well-known example of the multi-functional Swiss army knife, a universal method provides a reasonable device for a broad range of applications. However, when the focus is turned onto a single field of application, there is much to be gained by specializing the device towards that specific field. This is why a cook uses a cook's knife rather than a Swiss army knife, a diver uses a diver's knife and a sailor a sailor's knife. Investigating creative problem solving for a single field of application is likely to provide new knowledge that may lead to improvements for the application within that field.

Some recent publications argue that creativity is, at least to some extent, domain related, rather than a trait that is independent of any specific domain. For instance, in their review of case study research on highly creative people, Policastro & Gardner (1999) state that creativity is related to expertise within a specific domain:

A domain-centered analysis challenges the psychometric notion that creativity is an abstract property that some individuals have regardless of their previous experience or the domain that is under consideration. Research shows that even creative masters need a significant period of specialized training and practice in a particular cultural domain before they can make a significant breakthrough. (p.216)
Ward, Smith, & Finke (1999) reach similar conclusions coming from a cognitive standpoint:

... there is considerable evidence that creative performance is tied to expertise in a particular field, which enables the person to retrieve relevant information and to recognize when a new idea is likely to be valid or significant (e.g. Clement, 1989; Langley, Simon, Bradshaw, & Zytkow, 1987; Perkins, 1981; Weisberg, 1986). (p. 207-208)

In addition to the required knowledge or expertise within a domain required for creativity, the creativity-related skills may also be domain-specific. Taking a domain-specific perspective on creative problem solving may provide substantial insights into the application of the method within that domain.

1.4.2 Creative Problem Solving as a design method

The domain under consideration in this thesis is product design, also referred to as industrial design engineering. Buijs (1997) provides the following working definition of the domain, "Industrial Design Engineering is the development of durables (mass-produced products) for people, based on the integration of interests of users, industry, society and environment". Here the domain is referred to as 'product design' because this is a term more commonly known in the field (e.g. Roozenburg & Eekels, 1995).

There are two main motivations for focusing on the domain of product design. The first is that design has been a strong source of insights into the characteristics of phenomenon of creativity. Some of the main studies on creativity have included designers. For instance, MacKinnon (1965) in his research on the characteristics of creative persons used architects as subjects. He explains:

...why should architects be chosen as the profession to be studied? It seems to me, and to my collaborator in this research, Wallace B. Hall, that architects might as a group reveal that which is most characteristic of the creative person. If an architect's designs are to give delight, the architect must be an artist; if they are to be technologically sound and efficiently planned he must also be something of a scientist, at least an applied scientist or engineer. Yet clearly if one has any knowledge of architects and their practice, one realizes that it does not suffice that an architect be at one and the same time artist and scientist if he is to be highly creative in the practice of his profession. He must also to some extent be businessman, advertiser, author-journalist, psychiatrist, educator, and psychologist. (p. 273)

Product design shares a number of these characteristics with architecture. Christiaans (1992) mentions that the domain of product design integrates four sub-disciplines: engineering, aesthetics/styling, ergonomics, and new product
development (innovation management and marketing). These sub-disciplines cover many if not all of the characteristics of the field of architecture as mentioned by MacKinnon.

The second motivation for focusing on this domain is that methods for stimulating creativity have a history within design methodology. In his textbook on design methods, Jones (1970) already categorizes brainstorming and synectics as, "design methods that have been invented to stimulate "creativity" (p.47). Jones mentions two other methods of searching for ideas, namely 'removing mental blocks' and morphological charts. Almost twenty years later, Cross (1989) describes largely the same methods for generating alternatives. He categorizes brainstorming, synectics, and 'enlarging the search space' - which is essentially the same as Jones' 'removing mental blocks' - as design methods that are intended to stimulate creative thinking. Cross considers the morphological chart to be a rational, rather than creative, method for generating ideas.

In product design education, creative problem solving is integrated into the curriculum. This is the case at the Delft School of Industrial Design Engineering (see Buijs and Nauta, 1991), in which creative problem solving is introduced in the first and second year within the design studio work and as part of a course in integrated new product development. In the fourth year of the curriculum there is an advanced course in facilitating creative problem solving meetings. Another school that offers a product design program that is comparable to the Delft program is the Stanford Design Division in California. In their undergraduate and graduate programs creative problem solving techniques are integrated with courses in idea sketching, an approach developed by Robert McKim (1972). In Delft, sketching skills and creative problem solving skills are taught independently.

In addition to its uses in theory and education, creative problem solving is commonly used in design practice. The extensive use of brainstorming meetings at IDEO reported by Sutton & Hargadon (1996) (see the previous section) provides an example of the use of creative problem solving in meetings in design practice.

In The Netherlands we found some evidence that practicing product designers use creative problem solving as part of their repertoire of design methods as well. A preliminary survey among Delft Industrial Design Engineering graduates (n=29) shows that designers use creative problem solving regularly, partly within formal meetings, but also integrated within regular team meetings (Van der Lught & Buijs, 1998). In response to the question why designers chose to organize creative problem solving meetings, two main categories of motives emerged. The first category consisted of group issues (44%). Designers organize creative problem solving meetings because they are conducive to team effectiveness, provide commitment to the problem, and because they allow for multi-disciplinary contributions. The other main category related to the results of these meetings (38%). Designers organize creative problem solving meetings because of the quality
and quantity of ideas that are obtained, or because a break-through is needed in the design project. This is congruent with Sutton & Hargadon's notion that there are significant functions of creative problem solving meetings beyond the quality and quantity of ideas generated, when viewed within the context of team design projects.

To summarize the discussion, product design renders a suitable domain for advancing creative problem solving. On the one hand, it is suitable because product design is closely related to creativity, due to the integrative character of the domain. On the other hand, it is suitable because there is an identified tradition of integrating creative problem solving techniques within product design theory, education and practice.

1.4.3 A detected need for visual expression during idea generation

One of the main issues at stake when looking at tailoring the creative problem solving process to product design may be the modes of expression used. The body of creative problem solving techniques available is strongly based on the use of words to capture ideas, while in product design visual expression is an important mode of expression (e.g. Ullman, Wood, & Craig, 1990). More than being a mere way of presenting ideas, the application of visual expression by itself can be a means of stimulating creativity (e.g. McKim, 1972; Edwards, 1986). Including visual expression in creative problem solving techniques may enhance their applicability as design methods.

At the Delft Industrial Design Engineering course on facilitating creative problem solving, students repeatedly made alterations to existing creative problem solving techniques in order to allow for sketching. Apparently, these design students experienced a need to include the use of visual expression in creative problem solving activities. Some of these techniques, like the brainsketching technique, which will be described in more detail in the next section, became part of the standard portfolio of divergent thinking techniques used in the Delft School of Industrial Design Engineering.

This thesis concerns creative problem solving techniques that involve physical visual activity, like drawing. Our interpretation of visual creative problem solving techniques is related to stimulating creativity through visual 'doing'. Other interpretations of visual creative problem solving techniques may involve visual stimulation. For instance, a facilitator may show a picture of a landscape and ask the participants to use items of that picture for making associations. Or, visual creative problem solving techniques may be interpreted as being related to visual imagery. For example, participants may be asked to mentally visualize a future situation in which the problem has been solved and from there, move towards ideas based on this imagery.
A brief examination of creative problem solving text books and books on collections of techniques points out that very few creative problem solving techniques available in the literature make use of sketching, or other types of visual expression. Table 1.1 gives an overview of some well-known collections of creative problem solving techniques. For each collection, creative problem solving techniques that use visual activity are identified. In addition to the techniques that use visual expression, techniques that make use of imagery or picture stimulation are identified. The collections in the table were selected, because they are well known, complete, or seminal to the field. No collection of creative problem solving techniques was uncovered that provided descriptions of visual techniques, other than the techniques mentioned in the table.

<table>
<thead>
<tr>
<th>Book:</th>
<th>Total number of idea generation techniques</th>
<th>Visual stimulation techniques</th>
<th>Visual thinking techniques</th>
<th>Visual expression techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methoden und Organisation der Ideenfindung in der Industrie</td>
<td>24 I</td>
<td>2</td>
<td>0</td>
<td>1 II</td>
</tr>
<tr>
<td>(Methods and organisation of idea finding in industry)</td>
<td></td>
<td>- Bildmappen</td>
<td></td>
<td>- Gallery method</td>
</tr>
<tr>
<td>(Battelle Institut, 1972)</td>
<td></td>
<td>- Brainwriting</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Visual group</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>confrontation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Techniques of structured problem solving (first edition)</td>
<td>28</td>
<td>2</td>
<td>0</td>
<td>0 III</td>
</tr>
<tr>
<td>(VandGundy, 1980)</td>
<td></td>
<td>- Battelle bildmappen</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Brainwriting</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Visual synectics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Techniques of structured problem solving (second edition)</td>
<td>61</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>(VandGundy, 1988)</td>
<td></td>
<td>- Battelle bildmappen</td>
<td></td>
<td>- Symbolic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Brainwriting</td>
<td></td>
<td>representations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Visual synectics</td>
<td></td>
<td>- Brainsketching</td>
</tr>
<tr>
<td>Problemen oplossen met creatieve technieken (Solving problems with</td>
<td>21</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>creative techniques)</td>
<td></td>
<td>Meta-morphosis analogy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Wairovans, 1994)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>101 Creative Problem Solving Techniques (Higgins, 1994)</td>
<td>70</td>
<td>1</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Picture stimulation</td>
<td></td>
<td>- Visualization</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- Creative imaging</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- Excursion technique</td>
</tr>
<tr>
<td>Creative problem solving and opportunity finding (Couger, 1995)</td>
<td>26</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- Associations/ images</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>technique</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- Peaceful setting</td>
</tr>
<tr>
<td>Toolbox for creative problem solving (Isaksen et al. 1998)</td>
<td>9</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Visually Identifying</td>
<td></td>
<td>Imagery trek</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Relationships</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Photo excursion</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1.1: Visual creative problem solving techniques in the literature
In their research project to identify creativity techniques, the Battelle Institute identified over 200 techniques and in the process added about ten themselves to overcome the limitations of the techniques found (Battelle Institute, 1972). Examples of these techniques developed by the Battelle Institute are brainwriting and visual group confrontation.

The Gallery method is described as a technique that allows for sketching activity, and is therefore regarded especially suitable for a design context. However, the Gallery method does not consider visual activity as an integrated part of the technique.

The Gallery method is also mentioned in VanGundy's Techniques for structured problem solving (1980). However, he does not mention the use of sketches as a medium for generating ideas. In his version of the Gallery method, group members write down ideas on the sheets of paper.

Of all the techniques described in these collections, hardly any incorporate visual modes of expression. Techniques that make use of visual thinking and visual stimulation are slightly more common. The three techniques that include visual expression found are the ‘gallery method’, ‘symbolic representations’, and ‘brainsketching’. Below, brief descriptions of these techniques are provided.

• In the gallery method, group members record their ideas on big sheets of paper for about thirty minutes. Then they observe each other’s ideas as if they were in an arts gallery. Group members then return to their sheets of paper and elaborate on their ideas by using the input from the other group member’s ideas. The gallery method does not explicitly invite sketching, but according to the Battelle Institute (1972) the technique does provide enough time for designers to work out their ideas individually, possibly by means of sketching.

• Symbolic representations consists of –more or less intuitively– drawing symbols to represent the problem situation, which can then be re-interpreted in order to uncover new aspects of the problem. VanGundy (1988) also mentions a technique called ‘sculptures’ which consists of intuitive clay modeling, upon which the sculptures are re-interpreted.

• Brainsketching is a visual modification of the more widely known brainwriting technique (Geschka, Schaudie & Schlicksupp, 1973). Van Gundy (1988) mentions how this technique came into existence by students in his college class making a variation to an existing sentential technique. According to Van Gundy, they did so in order to satisfy their need for visual expression while generating ideas. As mentioned earlier, a similar development occurred at the creative problem-solving course at the Delft School of Industrial Design Engineering.

During brainsketching, group members individually sketch their ideas on sheets of paper. After a few minutes, the group members pass on the sheets and continue to sketch ideas, based on the ideas that are on the sheet already. Usually, about four to five rounds of idea generation take place. In between rounds, the facilitator may
emphasize the ‘building on other ideas’ guideline. Either, the sheets of paper are passed around between rounds, or the group members change position. This is the case when sheets are posted on the wall, as in figure 1.4.

![Figure 1.4: brainsketching in action](image)

In conclusion, there are few reports on techniques that make use of visual expression, of which only brainsketching appears to explicitly incorporate the designer’s need for idea sketching. The Gallery method merely allows for visual expression and the ‘symbolic representations’ technique is a technique for exploring the problem situation, rather than idea generation. It appears that the area of visual expression as a means of stimulating creativity in creative problem solving meetings is largely unexplored territory. In the introduction of this chapter, we have already mentioned that the dominance of written language, rather than visual expression, as a working medium may be explained by the notion that over the years, creative problem solving techniques have predominantly been applied and developed as managerial tools, rather than design tools.
1.5 Research issues

1.5.1 Limiting the scope of research

Before we can construct basic research questions to give structure to the research, the scope of this research needs to be narrowed down in order to provide sufficient focus. Figure 1.5 shows the relevant fields of research and the sub-areas that are of interest in this thesis.

![Figure 1.5: Limiting the scope of research](image)

As previously discussed, the main focus in this thesis is to develop creative problem solving as a method in product design, but as these fields are too broad for a directed search, specific areas of interest need to be identified. In the previous section, we identified visual expression as a promising area for further inquiry. Designers make extensive use of visual expression as a means of stimulating creativity; they make collages, quick foam models, diagrams, and especially sketches. Within design research, sketching is recognized as an especially powerful mode of visual expression, conducive to creativity in design (e.g. Fish & Scrivener, 1990; Goel, 1995; Goldschmidt, 1991; Schön & Wiggins, 1992). This suggests limiting the scope of this thesis to sketching as a specific mode of visual expression. In Chapter 2 of this thesis, existing theories on the activity of sketching in design are further explored.

The exploratory survey among product design professionals regarding the application of creative problem solving in design practice mentioned earlier (Van der Lught & Buijs, 1998) suggests that creative problem solving meetings are used throughout the design process. They are sometimes used for analyzing the design problem and, to a lesser degree, for developing ideas into design concepts. There are also reports of using creative problem solving meetings in the detailing phase, mostly dealing with sub-problems encountered while finalizing the product design. But creative problem solving meetings are predominantly applied in order to obtain perspectives on the problem space by generating a variety of different product ideas.
In addition to this, within design methodology creative problem solving techniques are regarded as techniques for generating design ideas (e.g. Jones, 1970, Cross, 1989, Roozenburg & Eekels, 1995). This suggests narrowing the scope to the activity of conceptual design (e.g. Pahl, Beitz, 1986) within the product design process.

As creative problem solving meetings are regarded as design methods for generating ideas, the scope is narrowed down by focusing on the Generating Ideas component of the creative problem solving process (see section 1.2). A second reason for focusing on the Generating Ideas component is that the advantages of sketching for design creativity as mentioned in the literature are closely related to generating design ideas, and consequently, the main effects of including sketching in creative problem solving are likely to occur within the Generating Ideas component. The creative problem solving techniques in this component are referred to as 'idea generation techniques'. This thesis concentrates on the category of associative techniques, as opposed to the categories of confrontative and structural idea generation techniques (Buijs, 1987). Confrontative techniques actively attempt to break existing thinking patterns, by forcing new, incompatible frames of reference into the problem situation. This is also known as bi-sociation (Koestler, 1964). Creative confrontation is a main principle in the synectics method (Gordon, 1960). Systematic techniques are based on decomposing the main problem into sub-problems. The sub-problems are solved, which leads to a number of sub-solutions. These sub-solutions are then combined, which provides solutions for the main problem. A widely known systematic idea generation technique is the morphological matrix (Zwicky, 1948). Associative techniques are based on the spontaneous reactions or associations to each other's ideas. Familiar associative techniques are brainstorming and brainstorming variations, like brainwriting. Associative techniques are the basic modes of operation in creative problem solving meetings. Even when confrontative or systematic techniques are applied, the separate divergent steps in these techniques consist of applying the mechanisms found in associative techniques. For instance, within the creative problem solving method, the previously mentioned morphological chart acts as a technique for generating ideas. The procedure for the morphological matrix, according to Isaksen et al (1994), is to sub-divide the problem into key parameters or sub-problems, to generate a variety of options for the parameters, and generate ideas on the basis of combinations of options. Both generating options for the parameters and generating ideas out of combinations of options involve associative idea generation. In order to allow for investigating the basic idea generation process, it is appropriate to focus on associative idea generation techniques.

In the remainder of this thesis, we will use the term 'idea generation meetings' to refer to these creative problem solving meetings in design, to emphasize the activity of generating ideas within these meetings.
Now that the scope of inquiry has been narrowed, by focusing on sketching as a particularly potent form of visual expression in product design, by focusing on the conceptualization phase within the product design process, and by focusing on associative idea generation techniques within the creative problem solving process, it is possible to construct the basic research questions in more detail.

1.5.2 Research questions
The focus of this study is investigating the ways in which sketching may contribute to idea generation meetings in product design. This leads to the two main research questions of this thesis. The first research question is related to achieving an understanding of the ways in which sketching may enhance or obstruct idea generation meetings in product design.

RQ 1: How do various ways of including sketching in idea generation meetings influence the group’s idea generation process?

The second research question is related to achieving an understanding of the ways in which sketching changes the idea generation process:

RQ 2: What are the differences in the structure of idea generation processes, when sketching or writing is used as a working medium?

In order to be able to answer these questions, a research approach needs to be developed that allows for determining the characteristics of the idea generation process. The majority of the methods available to assess creative problem solving meetings compare the outcomes of different experimental treatments, usually the quantity and/or quality of the ideas generated. The results-oriented approach is popular because of its robustness and its academic credibility. However, by discarding the process itself as object of research, the results-oriented approach leaves a rich source of information unutilized. If we are interested in the creative problem solving process, it is more informative to investigate the process itself, rather than investigating its results. This leads to a third, additional, research question that deals with developing a research method that provides insight into the characteristics of idea generation processes:

RQ 3: How can the idea generation process be described in such a way that differences in these processes can be analyzed, in order to answer the questions regarding the role of sketching in idea generation meetings?

1.5.3 Introduction to the remainder of this thesis
In this chapter we provided a summary of creative problem solving method, which included a brief review of research into the effectiveness of brainstorming meetings. We proposed a research direction for this thesis that investigates idea generation techniques in product design and, more specifically, idea generation techniques that
use sketching as a working medium. This leads to two basic research questions related to this research direction, and one research question related to the research method that needs to be developed.

In the remainder of this thesis we describe theoretical and empirical work done in order to answer these research questions. Chapter 2 examines the relevant literature in the field of design thinking research to achieve an initial understanding of the role of sketching in creative design groups. In Chapter 3 a research approach is identified and developed for examining the idea generation process. This research approach, called 'linkography', investigates the links between ideas, rather than the ideas themselves.

The presupposition behind the first research question is that both idea generation techniques and sketching help stimulate creativity, and that both ways of stimulating creativity can be superimposed. If this is the case, sketching can be added to idea generation techniques, without violating the basic principles. Chapter 4 describes the first empirical study, which has two objectives. The first is to explore various ways of including sketching in brainstorming meetings. The second is to explore whether the functions of sketching and brainstorming as means for stimulating creativity can be superimposed. The results of the study indicate that including sketching in brainstorming meetings structurally changes the process, which means that superposition is not possible.

This leads to shifting focus towards gaining further understanding of the differences of the idea generation processes, whether sketching or writing is used as working medium. This relates to the second research question. Chapter 5 describes an empirical study, which compares representatives of idea techniques that use writing or sketching as working medium.

The insights gained in this second empirical study make it possible to answer the first research question by making more refined inferences and postulations regarding the roles of sketching in idea generation meetings in design. In Chapter 6, the conclusions regarding the three main research questions are discussed and some further developments are made. Finally, some directions for applying sketching in idea generation meetings are provided, along with suggestions for further research.
The role of sketching in creative design groups

Sketches are the real heart of visual communication ... they serve both as individual thinking tools and as interactive communication tools. Recall the drafter who complained that she could not think without her drawing board. Sketches allow individual thinking and communication to occur simultaneously and hence facilitate distributed cognition. Thorough designers continuously use sketches, ranging from early drafts that are discussed with fellow designers and fabricators to rough drawings that are sketched in the margin to clarify an idea. (Henderson, 1999, p.203)

Introduction 2.1

In the first chapter of this dissertation, we discussed the rationale for taking a domain-specific approach to idea generation meetings. Regarding such meetings as design methods lead to identifying the functioning of sketching in design idea generation meetings as the principal area of interest. The assumption underlying this area of interest is that for designers both sketching and idea generation meetings are tools for stimulating creativity, and that combining the two may provide even better tools. Before embarking on empirical investigations into the ways in which sketching as a working medium functions in idea generation meetings, we need to develop a basic understanding of the ways in which sketching supports conceptual design activity, both for individual designers and design groups. By regarding idea generation meetings as specific kinds of design group meetings, we can infer which of these roles of sketching may also apply for idea generation meetings. Then, we can set up empirical studies to investigate these roles of sketching in idea generation meetings.

The role of sketching in group design activity 2.2

A basic categorization of design sketches 2.2.1

In his book 'Engineering and the mind's eye', Ferguson (1992) identifies three kinds of sketches, which may be useful for identifying the role of sketches in creative design groups: the thinking sketch, the talking sketch, and the prescriptive sketch.
- Thinking sketches refer to the designers making use of the drawing surface in support of their individual thinking processes. According to Ferguson, engineers use the thinking sketch "to focus and guide nonverbal thinking" (p.97).
• *Talking sketches* refer to designers making use of the (shared) drawing surface in support of the group discussion. Ferguson states: "...*talking sketches, spontaneously drawn during discussions with colleagues, will continue to be important in the process of going from vision to artifact. Such sketches make it easier to explain a technical point, because all parties in the discussion share a common graphical setting for the idea being debated*" (p.97).

• *Prescriptive sketches* refer to the designers communicating design decisions to persons that are outside of the design process. Ferguson describes the prescriptive sketch as the means for the engineer: "*to direct the drafter in making a finished drawing*" (p.97).

The prescriptive sketch is, according to McGown & Green (1998) "...*used almost exclusively within the latter detailing (pre-manufacture) phases of the design*" (p.436). The prescriptive type is not very relevant for this thesis, in which we are interested in the functions of sketching in conceptual design activity.

Ullman, Wood, & Craig (1990) propose an additional use of drawing in the design process, perhaps too obvious for Ferguson to report. Ullman et al state that the first use of the act of drawing is to "*archive the geometric form of the design*" (p.264). Sketches provide a means to store design ideas, so that they can be revisited at a later point in time. We will refer to this category of sketches as ‘storing sketches’.

• *Storing sketches* refer to the designers using the drawing surface to archive design ideas. Storing sketches have much in common with prescriptive sketches. They both record, rather than develop design ideas. However, the purpose of these two types of sketches is quite different. The storing sketch is intended for retaining information, whereas the prescriptive sketch is intended for communicating information.

In practice, a single drawing can have various functions at different moments in the process. For instance, a designer may generate ideas individually by means of sketching. This, in Ferguson’s view, is considered a thinking sketch. If the designer then explains his or her idea sketch, the thinking sketch turns into a talking sketch. And, if the designer moves on with further idea generation, the earlier idea sketch is archived on the drawing surface, which means that it turns into a storing sketch. Clearly, this classification based on Ferguson’s sketch types has its limitations, as each type of sketch solely covers one type of design activity. But it does provide the initial categorization desired to help organize theories on the roles of sketching found in design research literature.

### 2.2.2 The thinking sketch

In a review of the research on drawing and design, Purcell & Gero (1998) focus on the role of sketching in design cognition. This research is mainly concerned with investigating the ways in which the activity of sketching stimulates creativity in
design cognition. They point out underlying themes regarding the role of sketching in design. The principal theme deals with the positive role that sketching plays in re-interpretation. A second theme is that re-interpretation provides new knowledge and that this new knowledge leads towards further re-interpretation. Various researchers propose such cyclical models of re-interpretation, each with a slightly different connotation, ranging from a dialectic type of argumentation between seeing-as and seeing-that (Goldschmidt, 1991), interactive 'conversations' with the paper on which the designer draws (Schön & Wiggins, 1992), and movement from description to depiction (Fish & Scrivener, 1990). In order to provide a broad understanding of this re-interpretative process, the various perspectives will be described briefly.

Goldschmidt (1991) observes that architectural designers produce unclear, ambiguous sketches. She suggests that this is a substantial component of creativity in the design process. Designers often use sketches as metaphors for the objects to be designed. She calls this ‘interactive imagery’, which she defines as: "The simultaneous or almost simultaneous production of a display and the generation of an image that it triggers. Sketching, then, is not merely an act of representation of a preformulated image; in the context we deal with, it is, more often than not, a search for such an image" (p.131).

She proposes a dialectic type of argumentation in design. Based on protocol studies Goldschmidt points out that, while making idea sketches, architects use two types of reasoning in rapid oscillation. One type is based on analogical or metaphorical thought, dealing with extracting new meaning from the sketch. She describes this kind of reasoning as ‘seeing as’. The other type, ‘seeing that’, deals with the design consequences of this newly acquired meaning of the sketch. For instance, Goldschmidt provides the following example from her protocol study of a library design task. When observing her sketches over the footprint of the design location, one of the designers sees the surface area as a casbah (see figure 2.1): "For example, I can imagine this as a casbah..." Then, she extracts knowledge from this analogy, which Goldschmidt refers to as ‘seeing that’: "... where you have territories, confined territories".

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

Working in some visual medium -drawing, in our examples- the designer sees what is ‘there’ in some representation of a site, draws in relation to it, and sees what has been drawn, thereby informing further designing. In all this ‘seeing’, the designer not only visually registers information, but also constructs its meaning - identifies patterns and gives them meaning beyond themselves. (p. 135)
Schön and Wiggins also draw their examples from architecture: in fact, the sketch in figure 2.2 was made by a designer involved in a design experiment with the same library assignment as used by Goldschmidt in her experiments. The primary goal of the sketch is to support internal thought. Such sketches are almost void of communicative value. The link between the marks on the paper and the content that these marks refer to is very vague, probably only understandable by the designer that produced the sketch.

By means of this sketching activity, the designer was involved in experimenting with inner circulation and possible uses of spaces in the library. Schön & Wiggins interpret the designer's sketching activity in the following way:

> Her experiments, each intended to solve a particular problem, also lead to the discovery of new elements and relations in the footprint, cumulatively inducing a 'feeling for' the configuration – its dimensions and the relationships among its spaces. In her further designing, Clara makes use of these discoveries. But one might also say that her designing enables her to make these discoveries: she discovers to design, and designs to discover (p.154).

Another function of sketching identified by Fish & Scrivener (1990) is that sketching facilitates the transition from general descriptive knowledge into specific depiction. According to Fish & Scrivener the primary reason for designers to sketch is: "...the need to foresee the results of the synthesis or manipulation of objects without actually executing such operations" (p.117). In order to explain the functioning of sketching within design, the authors present a spectrum of visual representations, ranging from purely descriptive symbol systems to purely depictive symbol systems. Descriptive symbol systems can represent whole classes of information: they are abstract and categorical. An example of a descriptive symbol system is natural language. For instance, the word 'chair' may represent many different types of seats; sofas, office chairs, TV chairs, rocking chairs, and garden chairs are all covered under the label 'chair'. The information in such a descriptive symbol system is extrinsic, meaning that the object described by the symbol system is associated with the descriptive system solely by means of external definitions. The word 'chair' does not contain any of the qualities of the represented objects, neither in structure, color, nor in form. On the other side of the spectrum are depictive symbol systems, which carry all information about the represented objects within themselves, and do not depend on rules for extracting the information from the representation. These symbol systems are concrete and spatially specific, meaning that there is a direct relationship between the spatial position in the medium and the spatial position in the object represented. For instance, a picture of a rocking chair contains the topological information of that object. Depictive representations refer to specific objects, rather than classes of information.
Figure 2.3 shows how sketches and written language are positioned in relation to other types of representation within the proposed continuum. According to Fish & Scrivener, sketches have a special set of attributes that help the human mind in translating descriptive propositional information into depictive information. They theorize that in a creative design process this depictive information is then scanned, which leads to new descriptive propositional information, which in turn may be translated into depiction, and so on:

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

*(p.118)*

Fish & Scrivener identify three attributes of sketches that contribute to this description-to-depiction translation process.

*Sketches use abbreviated two-dimensional sign systems to represent three-dimensional visual experience.* A sketch is partly a depictive symbol system, because it contains spatial information about the design alternative represented. And, a sketch is partly a descriptive symbol system, because the abbreviations involved means that the representation also relies on extrinsically defined rules of interpretation.

*Sketches contain selective and fragmentary information.* This suggests interaction between the two-dimensional representation and the mental image of the design alternative under consideration. In addition to the abbreviations mentioned earlier, a sketch by itself does not provide sufficient information to confer all qualities of the design alternative represented. Information contained in the sketch and information contained by the mental images of the design alternative together constitute the representation of the design alternative. This notion is supported by the fact that sketches are often accompanied by sentential annotations. It suggests that the designer attempts to preserve some of the information provided by the fluid mental image by means of adding verbal descriptions in order to fill some of the gaps in the sketches.
• Sketches contain deliberate or accidental indeterminacies that are important to their function. An explanation provided by Fish & Scrivener is that these indeterminacies are important in order to preserve alternatives. An alternative explanation suggested by Fish & Scrivener is that sketches allow for graphic representations while parts of the object have not (yet) been defined. This is another trait of sketches that help the mind to move from propositional descriptive knowledge into depiction.

An example may help clarify these three attributes of sketches as proposed by Fish & Scrivener. The sketches in figure 2.4 are part of a group design workshop, which explores the possible consequences of adapting the metaphor of an elephant for the design of a vacuum cleaner.

![Figure 2.4: Design sketches of a vacuum cleaner based on the metaphor of an elephant (from Muller, 1997)](image)

The untidiness of the drawing in the upper right corner of figure 2.4 suggests that this drawing was produced in support of the idea generation process\(^1\). Many of the other drawings appear to have been produced to communicate or present ideas, rather than having a role within the process of generating design ideas itself. Figure 2.5 provides a close-up of this drawing.

The curved line across the 'body' of the vacuum cleaner (marker 1 in the figure) provides an example for sketches using abbreviated visual sign systems, which is the first attribute mentioned by Fish & Scrivener. The curved line suggests a certain roundness of the body. This line is interpreted as referring to roundness of the body, because of the extrinsically defined rule that such a line refers to a wire-form-like representation of the body.

The short lines between the air inlet with the main body of the vacuum cleaner (marker 2) can be seen as an example of the second attribute of sketches - containing selective and fragmentary information. In the sketch, a line (marker 3) marks the connection between the shapes of the air inlet and the body.

![Figure 2.5: Design sketch of a vacuum cleaner (Muller, 1997)](image)
The short curved lines mentioned soften the transition without changing the geometry of the air inlet and body. They do not show whether such a smooth connection is actually possible, or how it could be achieved.

An example of the third attribute of sketches—containing deliberate or accidental indeterminacies—can be observed by the various alternatives of handles present in the sketch (markers 4, 5 and 6). The sketch allows for three different, and probably conflicting, handles to be present within the same sketch. The first is a straight handle positioned lengthwise (marker 4). The second is a single curved line, suggesting a rounded handle lengthwise (marker 5). The third is a thick curved line on top of the body in cross-direction (marker 6), which could be interpreted as the end of the air-inlet hose, but it could also be interpreted as an alternative handle.

In their theory, Fish & Scrivener assume the—at least partial—existence of mental images of design alternatives. For many years now, there has been a strong debate in cognitive science about whether such mental images exist at all (see Kaufmann, 1980 for a review of this argument), and this debate has influenced design thinking research. Goldschmidt (1991) and Schön & Wiggins (1992), for instance, contradict the existence of mental representations of design alternatives. They postulate that design alternatives come into existence on the drawing board, and not in the mind’s eye (for a recent addition to this side of the argument, see Liddament, 1999).

Arnheim (1993) posits that, even if there were complete mental representations of design ideas, sketches cannot make exact copies of these mental images. In a reaction to Goldschmidt’s (1991) essay on the dialectics of sketching, he comments: "Drawings from mental images ... rely on generalities, on the simplifications that remain in memory as abstractions from the multiplicity of individual experiences" (p.16). According to him, by sketching, the designer creates an external representation of the design alternative that is, by definition, different from the mental image. Interpreting the qualities of the thus created image helps the designer to infer new directions for further generation of design alternatives.

These theories provide two general roles of sketching within the designer’s individual process that need to be considered when investigating sketching in idea generation meetings in product design. First, sketching is said to allow for tentative and non-committal moves from general description towards specific depiction. Secondly, sketching is said to involve a cyclical process of re-interpretation.

The talking sketch

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

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

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

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

According to Scrivener & Clark, sketching provides representations of design solutions that allow for a range of interpretations of elements. By sketching, temporal decisions are made which allow for evaluation and interpretation of a design solution, without excluding alternatives. Goel & Pirolli (1989) also stress the importance of the underlying processes taking place when sketching is concerned, in addition to their function of providing representations of design ideas. They also mention how the purpose of a sketch changes over time, as was discussed before:

Within a single symbol system, he [the designer] constructs multiple representations of the artifact. In both cases, we want to note that these external representations are not for communicating something after the fact. They serve an indispensable role in the generation, evaluation, and decision-making process. Once decisions are made, symbol systems serve to record and perpetuate them. (p.32)
So, while a sketch is created, it supports the group's immediate problem solving activities. After that, the sketch takes on a function of archiving the idea (and the related discussion) for later use. This 'storing' function of sketches will be discussed later.

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

According to Tang, the act of sketching is a means of communication and attracting attention, as well as it provides a medium for storing information.

Apart from its function of stimulating re-interpretation, the indeterminacy of sketches may also provide an obstacle to the prescriptive sketch. As Fish & Scrivener (1990) remarked, sketches are symbol systems that partially relate to externally defined rules of interpretation. In the case of sketching, these rules are mostly culturally acquired and are not explicitly defined. This external location of rules of interpretation may provide a negative account of re-interpretation in design sketching, namely misinterpretation. Eckert, Cross, & Johnson (1999) investigated communication through sketches within the knitwear industry. They found many problems in the communication between the designers and the technicians who set up the production facilities. For example, they report that technicians frequently ignore the fashion designers' sketches and develop the design solely based on the -often scarce- written information available. This miscommunication aspect is especially relevant for the prescriptive sketch, when a designer intends to communicate a finished solution, as in the knitwear industry example. We have already mentioned that prescriptive sketches are not very relevant in the early conceptual phase of the design process, in which we are interested. Miscommunication may be relevant for the talking sketch, if sketches are undetermined to such extent that they do not provide sufficient information for the group members to interpret them.

**The storing sketch 2.2.4**

The previous section dealt with the role of sketching in design thinking and communication. The storing sketch deals with the role of sketching in archiving and retrieval of design information. According to McKim (1972) building and maintaining a -what he calls- 'collective graphic memory' fosters the group's creative process by providing an easily accessible database of design information, which stimulates building on earlier design ideas (see figure 2.6).
The functioning of the collective graphic memory is closely related to our understanding of the functioning of the storing sketch.

In the design literature little relevant information can be found concerning the storing sketch. However, in the field of visual cognition, differences in recognition of words and pictures have been subject of investigation. This research is relevant for the storing sketch, if we consider a sketch to be a type of picture. There is proof that pictures of objects can be categorized more rapidly than words that describe these objects (Potter & Falconer, 1975). But, if the objects from the different categories share many physical characteristics, this advantage of pictures over words may be lost. In that case, categorization for pictures may even be slower than for the word condition (Snodgrass & McCullough, 1986). This relates to the depictive qualities of sketches. By sharing actual attributes of the (imaginary or real) object they refer to, sketches provide stronger distinctive features than words. Humphreys & Bruce (1989) hypothesize:

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

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

Potential functions of sketching in idea generation meetings

2.3

The main objective of this thesis is related to exploring the ways in which sketching
affects the idea generation process in idea generation meetings in product design.
From the design literature, and literature in adjacent relevant fields of research, we
identified various functions of sketching. Functions related to the thinking sketch
support individual design thinking. Functions related to the talking sketch support
design group interaction and discussion. Functions related to the storing sketch
support the retrieval of previously generated design information.

If we acknowledge that both informal design group meetings and idea generation
meetings are, in fact, problem solving group meetings, then the functions of
sketching as found for the design groups can also be applicable for idea generation
meetings in product design. The emphasis of the various roles of sketching may be
different, but the general functions of sketching as detected in design groups are
likely to be present in idea generation meetings in design. This leads to the
following potential functions that sketching may have in idea generation groups in
design.

• Thinking sketches stimulate a re-interpretive cycle in the idea generation process.
The roles of sketching for individual problem solving are still present for the
individual designers in a group context. To recall the roles found in literature: 1)
Sketching helps moving from general descriptions to specific depiction; 2) By means
of its indeterminacy, sketching stimulates a cycle of re-interpretation. The second
role is especially relevant for idea generation meetings, as the general goal of such
meetings is to provide a variety of novel ideas. The first role of facilitating
movement from general descriptions towards specific depictions of ideas is more
relevant for the later phases of an idea generation process, in which a higher level
of resolution is desired.

• Talking sketches stimulate re-interpretation in the idea generation process.
The typical group aspects of sketching found are: 1) The indeterminacy of sketches
invites re-interpretation; 2) Sketches stimulate idea development by allowing for
relatively advanced types of reasoning without having to commit to single
solutions; 3) Misinterpretation of each other’s sketches could happen, when
designers’ sketches are too vague to be interpreted by the other designers.
The third aspect, of potential miscommunication is not very relevant for idea
generation meetings. In these meetings, such miscommunications are often
welcomed, because they may provide radical new insights. As with the individual
functions of sketching, the second aspect -which suggests that sketching stimulates
development of ideas - is more relevant for the later phases of an idea generation process, in which more refined ideas are required. The first function of inviting re-interpretation is especially relevant for idea generation process, as re-interpretation leads to novel directions for generating ideas.

- **Storing sketches stimulate the use of earlier ideas by enhancing their accessibility.**

For the storing sketch we detected one function, enhancing the accessibility of earlier ideas. Improving the availability of these ideas available for the group members to refer back to is very relevant for idea generation meetings, because 'building on each other's ideas' is one of the four guidelines for divergent thinking. Enhancing the accessibility of the earlier ideas can lead to a better-integrated idea generation process, which is regarded as a positive quality of the idea generation process (see section 3.2).

**Notes**

1 It is not exactly clear whether this sketch was produced in support of an individual designer's cognitive process, or in support of a design group's process. In any case, the sketch does provide examples of the attributes of sketches proposed by Fish & Scrivener.
Research approach: Linkography

Introduction

This chapter addresses the research question relating to the method for analyzing the empirical data: How can the idea generation process be described in such a way that differences in these processes can be analyzed, in order to answer the questions regarding the role of sketching in idea generation meetings? First, the rationale is provided for taking an approach that studies the characteristics of the idea generation process itself, rather than the approach-dominant in the field of creativity research-of studying the characteristics of the resulting ideas in order to make inferences about the idea generation process. Then, an appropriate method for studying the process is identified, namely ‘linkography’ (e.g. Goldschmidt, 1995). This method was developed and used for describing design activity. Finally, linkography is adapted and developed further as a research approach for studying idea generation meetings. We will continue to develop linkography throughout the empirical work.

A process perspective to examine idea generation meetings

The dominant outcomes approach in research on the creative process

The majority of the empirical research on the functioning or the effectiveness of creative problemsolving techniques uses experimental designs, in which differences in outcomes are compared between a group receiving a certain ‘treatment’ and a control group. The treatment typically consists of a certain idea generation technique applied to the group (e.g. Bouchard, 1972; Dunnette et al, 1963; Diehl & Stroebe, 1991; and more recently, Nijstad, 2000). The control group is subject to either no treatment, or a more conventional type of idea generation technique. The outcomes usually consist of the quantity, and sometimes the quality, of the ideas generated. As most of these studies refer to the quantity of ideas, or quantity of ‘good’ ideas generated per person per time unit, they really investigate the supposed efficiency, rather than the functioning of creative problemsolving meetings. Functioning is assumed to correspond with efficiency, perhaps for the pragmatic reason that efficiency can more easily be operationalized into relatively objective dependent variables.

The quality, or creativeness, of products is mostly studied using psychometric approaches. A well-known example in the field of creativity research is the Creative Product Semantic Scale (Besemer & O’Quin, 1986), which is used by non-expert
raters to assess the creativeness of products along three dimensions with, in total, eleven sub-scales: Novelty (Original, Surprising, Germinal), Resolution (Valuable, Logical, Useful), and Elaboration and Synthesis (Organic, Elegant, Complex, Understandable, Well-crafted). The instrument is not meant to provide a single, cumulative creativity score. Rather, the sub-scale scores are used to provide a more expressive understanding of the product's creativeness.

Another approach to assess the creativeness of products is exemplified by Amabile (1996) who uses the opinions of expert judges. The underlying belief is that experts 'know creativity when they see it'. Amabile conveys a consensual definition to creativity:

A product or response is creative to the extent that appropriate observers independently agree it is creative. Appropriate observers are those familiar with the domain in with the product was created or the response articulated. Thus, creativity can be regarded as the quality of products or responses judged to be creative by appropriate observers, and it can also be regarded as the process by which something so judged is produced. (p. 33)

This approach prefers to study the creativeness of products as a whole, rather than breaking it down into separate dimensions. It evades the complex question of defining what characteristics make a product creative. Christiaans (1992) applied Amabile's expert judges method in order to assess the creativeness of concepts generated in design experiments. His research is an example of the outcome research perspective for judging creativity in the design process.

In order to point out how dominant the outcome research perspective is within the field of creativity research, a selection of the better-known studies on the 'effectiveness' or functioning of idea generation techniques is provided below. Table 3.1 shows the reference for the publication, a short description of the study, and the dependent variables used. The results of the studies are put in brackets, as it is not the intention to shift the focus towards the effectiveness of idea generation meetings. Instead, this table is meant to exemplify the predominance of the outcomes research. The selection is mainly based on the bibliography on experimental evidence regarding creative problem solving, as provided by Isaksen (2000) and the internet-accessible CBIR (Creativity Based Information Resources) database of the Center for Studies in Creativity in Buffalo, NY (www.buffalostate.edu/~cbir/). This database contains over 11,500 annotated entries on the subject of creativity and provides an excellent starting point for literature searches on the subject of creativity.
<table>
<thead>
<tr>
<th>Study</th>
<th>Description</th>
<th>Dependent variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bouchard, T. J., Jr. (1972). A comparison of two group brainstorming procedures. <em>Journal of Applied Psychology</em>, 56 (5), 418-421.</td>
<td>Compares the effectiveness of regular brainstorming procedures and brainstorming modified by adding a synectics component (personal analogy) in two different treatment conditions, high and low, interpersonal effectiveness groups. (Results: the groups using synectics generated more different ideas. No significant differences resulted from the selections by interpersonal effectiveness, nor were there any interactions.)</td>
<td>Quantity of solutions: Number of different ideas.</td>
</tr>
<tr>
<td>Diehl, M., &amp; Stroebe, W. (1991). Productivity loss in idea-generating groups: Tracking down the blocking effect. <em>Journal of Personality and Social Psychology</em>, 61 (3), 392-403.</td>
<td>Four experiments with student groups to investigate individual and group differences on brainstorming productivity between real and nominal groups. (Results: production blocking, evaluation apprehension and free riding are given as the three major interpretations to account for lower brainstorming productivity in real groups.)</td>
<td>Quantity of solutions: Quality of solutions</td>
</tr>
<tr>
<td>Dunnette, M. D., Campbell, J. P., Jaastad, K. (1963). The effect of group participation on brainstorming effectiveness for two industrial samples. <em>Journal of Applied Psychology</em>, 47, 30-37</td>
<td>Experiment with research scientists and advertising personnel brainstorming as individuals and as groups. (Results: individuals produced more and higher quality ideas than those produced in the four member groups. It was found that group work followed by individual brainstorming yielded more and better ideas.)</td>
<td>Quantity of solutions: Quality of solutions</td>
</tr>
<tr>
<td>Ekwall, G. &amp; Parnes, S. J. (1989). Creative problem-solving methods in product development: A second experiment. <em>Creativity and Innovation Yearbook</em>, 2, 122-142</td>
<td>Effects of training and application of four different idea generation strategies (brainstorming, brainstorming combined with analogy thinking principles, morphological analysis, and creative group leadership (Maier, 1963)) are related to each other and a control group condition. (Results: brainstorming with analogy performed better than all the other techniques, including the control group. The implicit hypothesis that any of the techniques is better than no technique had to be rejected).</td>
<td>Quantity of solutions: along three dimensions: Usefulness, originality, elegance.</td>
</tr>
<tr>
<td>Lewis, A. C., Sadosky, T. L. &amp; Connolly, T. (1975). The effectiveness of group brainstorming on engineering problem solving. <em>IEEE Transactions on Engineering Management</em>, 22 (3), 119-124.</td>
<td>Study seeking to determine the value of group idea generation exercises as compared to individual brainstorming efforts. Experiments were done with 2-man, 4-man, 6-man and nominal group situations. (Results: combining results of individual idea generation efforts produces more useful results than group brainstorming.)</td>
<td>Quantity of solutions: number of useful results</td>
</tr>
<tr>
<td>Fiestien, R. L. &amp; McGowan, R. J. (1988). Creative problem solving and communication behavior in small groups.</td>
<td>Study of the differences in communication behaviors between small groups trained in Creative Problem Solving and those not trained in CPS. (Results: groups trained in CPS participated more, criticized ideas less, verbally supported ideas more, used more verbal and non-</td>
<td>Quantity of solutions: Communication process: amount of participation.</td>
</tr>
</tbody>
</table>
| Grieskiewicz, S. S. (1980). *A study of creative problem solving techniques in group settings*. Unpublished doctoral dissertation, University of London. | Two experiments concerning the use of individual and group idea generation techniques among managers. Guided fantasy, brainstorming and brainwriting were used. (Results: nominal brainstorming may exceed real brainstorming in fluency production; real brainwriting displayed greater fluency than nominal brainwriting or real brainstorming; and guided fantasy appeared to produce greater idea quality than the other two techniques.) | Quantity of solutions (fluency J) 
Quality of solutions |
|---|---|---|
| Rickards, T. (1975). *Brainstorming: An examination of idea production rate and level of speculation on real managerial situation*. *R & D Management*, 6 (1), 11-14 | Experiment to examine production of ideas and levels of speculation of brainstorming groups. (Results: consistent with deferment of judgment principle) | Quantity of solutions 
Quality of ideas: level of speculation |
| Runco, M. A. & Okuda, S. M. (1988). *Problem discovery, divergent thinking, and the creative process*. *Journal of Youth and Adolescence*, 17 (3), 211-220 | A study with adolescents, to investigate the importance of problem finding, by using discovered (open ended) problems or presented problems. (Results: subjects gave significantly more ideas for discovered problems (open-ended problems) than presented problems. The small correlation between discovered and presented problems implies that problem finding is a developed skill and becomes distinct during adolescence.) | Quantity of ideas |

*I Fluency, flexibility and originality are dimensions coined by Guilford (1977), and used by Torrance (e.g. 1979) in tests for assessing creative ability. They are alleged to be measures of process, but they are measured by examining the range of ideas generated. Therefore, in this comparison, fluency (scored by counting the number of varying ideas generated), flexibility (relates to the number of different categories of ideas generated) and originality (refers to the statistical infrequency of ideas generated, in reference to the norm) are primarily considered to be outcome dimensions.*

Three of these studies use the quantity of solutions as the sole indicator for the functioning of the techniques used. One study depends on the quality of ideas, and five use both quality and quantity as dependent variables. One study looks at a combination of quantity of ideas generated and various types of communication behavior, mainly due to the fact that investigating communication behavior was the main purpose of this study. No weight can be given to any inferences made based on this sample, as the selection of articles does not attempt to provide an overview of the research on the effectiveness of idea generation meetings. It is merely meant to provide an illustration of the predominance of using the quantity and quality of ideas as dependent variables in creative problem solving research by identifying some of the principal research efforts. We were not able to find any study within the CBIR database that assessed the value or effectiveness of idea generation meetings by means of dependent variables other than the quantity and/or quality of the resulting ideas.

These research methods that use the quantity and/or quality of the ideas generated as a means of inferring the functioning of idea generation processes can be considered 'black box' approaches. The contents of the black boxes -the
characteristics of the idea generation processes are considered irrelevant. Only inputs and outputs of the black boxes are of interest to the researcher. The contents of the black boxes are disregarded, not because they are uninteresting, but because they are not easily accessible for objective comparison.

In the previously described research design, the input is altered by means of, for instance, a new idea generation technique. Then, the output of the 'black box' is measured and compared to the output of the control group. A graphic depiction is provided in figure 3.1:

![Diagram](image)

The focus on outcomes stems from the fact that research in creativity has had difficulty in being accepted as an issue worth investigating in psychological research. Ever since Guilford's presidential address to the American Psychological Association (1950) which put the subject of creativity on the psychologist research agenda, researchers have attempted to make research into creativity as robust as possible, in order to make studies into the fluid phenomenon of creativity acceptable to the psychological research community. This overcompensation is likely to have lead to the dominance of the outcomes approach.

Consequently, studies into the functioning or effectiveness of idea generation groups mainly assess the quality or the quantity of ideas generated, as the main claims regarding the value of idea generation meetings are related to these two aspects. The more rigid behaviorist research approaches only accept the quantity of ideas generated as a reliable measurement of the functioning or effectiveness of idea generation meetings (e.g. Hocevar, 1979), mainly because it is the only dependent variable that is directly observable.

**The rationale for taking a process perspective**

There is a structural problem with the 'outcomes' approach. It is questionable whether the quality and quantity of ideas generated is an appropriate measure of the functioning of idea generation meetings. The aim in the conceptualization phase of the design process, in which idea generation meetings are mostly applied, is to come to, as French (1985) puts it, broad solutions to the design problem. In a design project, a limited number of solutions are needed, which may stem from a
few 'good' ideas, or even interesting combinations of ideas that by themselves could not be characterized as 'good'. This means that a large number of ideas, and even a large number of 'good' ideas, can hardly be accepted as measures for how well idea generation meetings contribute to the development of design solutions.

In the fields of both design and creativity research, creative problem solving is regarded as a search process (For the field of design, see Cross, 1989. For the field of creativity research, see Nickerson, 1999). Generation of a large number of ideas through brainstorming is one particular search strategy, described by De Bono (1992) as a 'scatter-gun' approach. Other approaches divide the 'solution space' into several sub-areas (like morphological charts). And yet other approaches try to explore the boundaries of the perceived solution space by attempting to widen the solution space, for instance by introducing random stimuli. The number of ideas generated may be an indicator for how well the 'strive for quantity' guideline for brainstorming is observed; it does not provide a measurement for the functioning of idea generation meetings in product design in general.

An alternative approach is to concentrate on the structure of the idea generation process itself, rather than the resulting ideas. The experimental set-up of such a process perspective is shown in figure 3.2:

![Figure 3.2: Basic systems model of process research](image)

Investigating the structure of the idea generation process can provide insights into the nature of the search process taking place. As one of the primary objectives of this study comprises of achieving an understanding of the functioning of sketching in CPS meetings, it is essential to examine what happens during the process of generating ideas. Differences in the structure of the process can identify the ways in which sketching influences the idea generation process in design groups.

### 3.2.3 Linking as a quality measure for the idea generation process

The main focus when looking at group processes should be directed towards the ways in which group members interact. Gruber (1980) states about the creative process: "Interesting creative processes almost never result from single steps, but rather from concatenations and articulations of a complex set of interrelated moves" (p 177-178).
Dorst (1997) suggests integration as an important factor in design activity. According to him:

... a product is a network of thought-out forms and properties, of objects and thought-out links between them which have been instilled with meaning. I would like to point out that in such a definition a 'product' is the total network of decisions that has been built up while designing, including the vast number of possibilities that were considered, but in the end rejected, information processed, but not directly used, the background theories that were used, etc. (p. 35)

By transferring this view of the industrial design 'product' towards the current investigations into the idea generation process, a well-integrated idea can be expected to show signs of making use of the information gained earlier in the process. Following this line of thought, a well-integrated idea generation process has a strong network of links. Therefore, in this study, well-integrated idea generation is an indicator for quality of process. This makes the 'seeking combinations' guideline of divergent thinking (see section 1.2) -which suggests building on each other's ideas- especially relevant. An idea generation process with a strong network of connections between ideas can be regarded as well-integrated.

Furthermore, it is important to achieve insights into the extent to which participants build on their own ideas, or on each other's ideas. The very reason for having a group meeting is for the group members to interact in their problem solving efforts, by making use of each other's knowledge and previous experience. This is especially relevant for multi-disciplinary teamwork -which is often the case in design projects (see section 1.1)- as these projects require the integration of knowledge from the separate disciplines represented, which cannot be accomplished by the team members separately. If the amount of building on their own ideas is very high, the group process is not well-integrated, even though the individual processes may have many connections with earlier ideas.

Finally, a distinction needs to be made between being well-integrated and Goel's (1995) concept of 'early crystallization', which means that the search for new directions for design solutions is abandoned prematurely. Early crystallization may lead to the designers often connecting to earlier ideas, because those ideas have become part of a rigid frame of reference. However, the types of these connections will be different than for a normal associative idea generation process. Early crystallization will involve a process of predominantly small alterations. In a well-integrated idea generation process, wild leaps, direct associations, and small alterations are balanced. Too many wild leaps indicate a lack of progress in the idea generation process, and too many small alterations indicate premature crystallization. These indicators for a well-integrated idea generation process are further developed in the 'applying linkography' section (section 3.5).
3.3 Linkography

3.3.1 Introduction
In creativity research, hardly any instruments take a process perspective for assessing the effectiveness of idea generation techniques. In their comprehensive review on creativity assessment instruments, Puccio and Murdock (1999) concur that: "Despite great interest in applying and teaching strategies and models of creative thinking (e.g. Torrance & Presbury, 1984), few measurements explicitly examine aspects of the creative process" (p. 14). Even though Puccio & Murdock state that there are 'few' explicit creative process measurements, they do not report any in their overview. Therefore, we will look for a suitable research approach in the adjacent area of design thinking research. This research area is more familiar with investigating the structure of problem solving processes.

3.3.2 Methods that analyze the structure of design processes
Analyzing the structure of design processes is often used in design thinking research, mainly through protocol studies (For an overview of the various approaches of applying protocol analysis in design thinking research, see Cross, Christiana, & Dorst, 1996). Already Newell & Simon - whose contribution of treating human problem solving as information processing systems (Newell & Simon, 1972) has been very influential in design thinking research - used graphic representations of the structures of problem solving processes. They used 'Problem Behavior Graphs', which show 'states of knowledge' in the nodes of the diagram, and 'operators applied to the states of knowledge' as connecting lines between the nodes. Figure 3.3 shows the overview of a Problem Behavior Graph of the problem solving process of an experimental subject working on a well-known cryptarithmetic puzzle (DONALD + GERALD = ROBERT).

The possibility of identifying such clear and determined states of knowledge in design activity has been questioned. For idea generation meetings it is very unlikely that one could identify such states of knowledge, due to the fuzzy nature of the idea generation processes occurring. Therefore the Problem Behavior Graph does not appear to be useful for analyzing the processes of idea generation meetings.

Dwarakanath & Blessing (1996) constructed 'decision trees' for design group experiments. Decision trees are customarily used as a design method, for exploring the solution space (e.g. Roozenburg & Eekels, 1995). Dwarakanath & Blessing proposed using the decision tree as a research method. They constructed decision trees of design experiments based on -what they interpreted as- the major problems and alternatives considered. Figure 3.4 shows the thus derived decision tree of the well-known Delft Protocols Workshop group meeting (Cross et al, 1996).
Figure 3.3: Problem Behavior Graph (Newell & Simon, 1972)

Figure 3.4: Decision tree of the Delft Protocols Workshop group design meeting as proposed by Dworakonath & Blessing (1996). Sloping lines refer to alternatives considered, vertical lines refer to sub-problems considered and horizontal lines refer to decomposition of the problem into sub-problems. Dotted lines refer to rejected paths in the design process.
Deferring judgment is one of the principal guidelines for idea generation meetings. This guideline dismisses the making of decisions from the divergent phase. Therefore, it is not very reasonable to attempt making decision trees for idea generation meetings, when one is interested in the actual activity of generating ideas.

Both the problem behavior graph and the decision tree require the researcher to backtrack the design process as if it were a rational decision making or reasoning process. The association processes that occur while group members generate ideas are quite distant from such rational processes, which makes these methods unsuitable for analyzing idea generation meetings. Other approaches (e.g. Takeda et al., 1996; Trousse & Christiaans, 1996) have principally the same difficulties, which disqualify them for application in the field of creative problem solving.

One research approach that does not rely on regarding designing as a rational decision making process is proposed by Goldschmidt (1996). This approach, known as linkography, directly addresses the ways in which designers make connections with previously generated design information by recording the links among design moves. According to Goldschmidt a design move is: "...a step, an act, an operation, which transforms the design situation relative to the state in which it was prior to that move" (p. 72). With linkography, Goldschmidt took a structuralist research approach (e.g. Levi-Strauss, 1972; Piaget, 1971). Structuralism is only interested in examining the structure of the relationships between elements. It is not interested in the qualities of the elements themselves.

3.3.3 Linkography as proposed by Goldschmidt

By analyzing the linking between the moves, linkography purports to: "...be instrumental in comprehending structural patterns of design reasoning" (p. 72). Here, a brief description of the linkography approach is provided. For more thorough descriptions of linkography, and the attempts by Goldschmidt to use linkography as a means to understanding the structure behind design reasoning, we refer to a series of publications by Goldschmidt on this subject (Goldschmidt, 1990, 1992, 1996; Goldschmidt and Weil, 1998).

The general approach followed by Goldschmidt is to first subdivide a protocol of a design experiment into moves. Then, links between moves are determined, based on common sense. She explains that: "In practice, a link between two moves is established when the two moves pertain to the same, or closely related, subject matter(s), such as a particular component of the designed entity, its properties and functions, a concept or a design strategy, and so on" (Goldschmidt and Weil, 1998, p.90). For each move, the existence, or non-existence, of links with each of the earlier moves is determined. These links are then displayed as a linkograph, which basically is a matrix that is transformed so that the diagonal is made the horizontal axis. This way, links between moves refer to a single axis, rather than in the regular
matrix display where links would refer to the horizontal and the vertical axis. See figure 3.5 for an example of a linkograph.

Moves can have links with earlier design moves, which Goldschmidt refers to as 'backlinks'. Moves can also have links with later moves, which she refers to as 'forelinks'. Goldschmidt then proceeds by assessing the so-called 'critical moves' in the linkograph. She explains: "Moves that generate a notably higher number of links are of particular interest: we call them critical moves (CMs) and we postulate that they are more important than other moves in terms of advancing the design process, i.e. its productivity" (Goldschmidt & Weil, p.91). In some of her studies, moves with six or more links are considered to be critical moves, but this requirement is varied according to the goals of the particular study.

She relates critical moves with a large number of forelinks to the creativity component of design productivity and she relates critical moves with a large number of backlinks to the knowledge-based grounding of ideas. She then uses these critical moves to make inferences regarding the design productivity in various design experiments.

In the design research community, Goldschmidt's approach has received praise. A paper in 'Design Studies' based on the linkography approach (Goldschmidt, 1995) received the journal's yearly 'Best Paper Award'. However, during the 1994 Delft Design Protocols Workshop (Cross et al, 1996) where the paper was first presented, some concerns regarding the research method were also expressed. The first concern relates to the use of 'design moves' to sub-divide the protocol. According to Goldschmidt, a 'design move' is determined by a change in the relative state of the design situation. The 'state of the design situation' can be assumed to correspond with Newell & Simon's 'state of knowledge'. This means that often it is not clear what the 'state of the design situation' is. Then it is even more difficult to determine changes in the relative state of the design situation. The second concern relates to the ways in which links are assessed. In Goldschmidt's method links are based on the rater's 'common sense', which endangers the reliability of the method, as this
way of coding is highly open to subjectivity. These two issues need to be addressed when adapting and developing linkography as a method for assessing the idea generation process.

Linkography is solely based on determining the existence or non-existence of connections between elements in the design process. The method does not require assuming a rational process of decision making or reasoning. Provided that we can overcome the concerns mentioned above, linkography is likely to provide a suitable method for investigating structure of the idea generation processes.

3.4 Adapting linkography

3.4.1 An idea generation meeting in product design

In order to explain adaptations made to the linkography method by means of examples from real design group situations, we will first describe an idea generation meeting with a design team. A section of the protocol of this meeting is used for developing the linkography method.

The ‘Timbuktu’ design team involved consisted of a group of six advanced product design students who, as a team, were involved in a large, five month, design studio project dealing with developing new product solutions for a real company. The design assignment for this team was to develop new products to be produced in Africa, and to be sold in Europe in the third world aid-shop circuit. The objective of the idea generation meeting was to generate a wide variety of product ideas for a previously selected search area\(^2\), which the designers identified as ‘daily spirituality’. This search area is aimed at the need in people to solidify emotions or events, by means of objects. One of the problem statements that were generated in the ‘understanding the problem’ component of the idea generation meeting was “How to connect with each other”. Ideas for this problem statement were generated with the brainsketching technique (see Chapter One for a description). An idea that was selected for further development consisted of two tuning forks (figure 3.6).

This ‘tuning forks’ idea was broadened towards "products that carry the same sound", and used as input for a short brainstorming step. The section of the protocol for this step is provided in table 3.2:

---

\(^2\) This search area concept is based on the idea of everyday objects that carry personal meaning and emotional value, such as traditional African music instruments or tools used in daily life.
Fac: Ideas...
D: Fred already has one...
F: You both have mice in your pocket and when you squeeze them they make noise ... it is best if they are brother and sister. (1)

(1h39min)
D: Some kind of whistle ... In Chili there is some whistle language, so that you can communicate over large distances. (2)
F: Those tuning forks that have the same tone and it is preferable that they resonate. (3)
H: Drums (4)
E: Castanets with tones that belong to each other (5)
F: Those toy animals, you squeeze them and then... eep! (6)
H: Something to put on your ankles... so that when you walk something (unintelligible) .. with a bell or something. (7)
D: Yes, something like a rattle (8)
F: Tinkerbell (9)

(1h40min)
Fac: Tinkerbell?
F: Yes that is a name for that rattle
D: I used to wear a little bell around my neck (10)
H: (laughs and pretends to be pushing a doorbell) Ding dong
F: Yes, something that makes the same sound, and when you hit it into each other, it makes a different sound. (11)
H: One person has the doorbell and the other has the button. (12)
F: I know of a couple who wore as corsage at a formal party, one person a computer mouse and the other a mouse trap (13)... that does not make sound or anything, but it is kind of the same thing ... like a plug and an outlet (14)

(1h41min)
Fac: Now you are kind of going back towards things that fit together... try going back to things that carry the same sound.
D: Those sorts of (points at an idea generated in the brainstorming meeting) wind chimes that you both have in front of your house. If the wind blows it is as if the other person blows into the chimes. (15)
I: Both a mosquito in a cage (16)
F: Yes, in a small glass tube (17)
H: In your ear . bzzz! (18)
D: An earring with a mosquito in it (19)
F: There is a cell phone company which has a subscription for partners ... so that you have a hotline (20)

(1h42min)
E: A vibrating implant (21)
Fac: Try to elaborate on that... what can you make from that which can be produced in Kenya?
F: They can make earrings, that is not an implant, but it is in your body (22)
D: An earring that caresses your neck (23)
F: With those soft things hanging from it (24)
D: Yes (1h43min)
I: Toucan feathers (25)
A: I have an idea for the product ... you can make some kind of a wind bag ... if you sit on it then ... pfft! (laughter) (26)
F: And that inflates again and again so that each time when he sits down again ... (27)

Table 3.2: Sample of the design group brainstorming protocol. Numbers in brackets identify idea fragments.
This brainstorming step is used for providing examples in adjusting the linkography method, and to determine the reliability of the research method. After the idea generation meeting, the designers had another sketching meeting in which they used the outcomes of the meeting for sketching more concrete product ideas. The ideas from this particular brainstorming step - dealing with 'products that carry the same sound' - were not developed further. However, another idea from the brainsketching step: 'things that fit into each other' was developed into a proposal of a series of three products: letter openers (figure 3.7), pendants, and candleholders with shapes that fit into each other.

3.4.2 Adapting linkography for analyzing idea generation activity

The linkography method is adjusted in order to make it applicable to idea generation meetings. For analyzing such meetings, we opt for investigating the linking between design ideas, rather than design moves. Even more so than in design activity, during idea generation meetings, it is impossible to speak of, in Goldschmidt's terms, 'a relative state of the design (problem solving) situation'. This makes identifying moves impractical. Instead of design moves, design ideas are identified as the primary units in the protocol.

Even though the term 'idea' is open to many interpretations, some basic criteria for identifying ideas can be developed. In Greek, the word 'idea' means 'appearance of a thing'. The creativity scholar Mel Rhodes, originator of the commonly used four P's of creativity (Person, Product, Process, Press) defines an idea as: "... a thought which has been communicated to other people in the form of words, paint, clay, metal, stone, fabric, or other material" (Rhodes, 1961, p. 309). This leads to the first of two minimum requirements for ideas to be included into the link system: Ideas need to have been communicated. There needs to be some kind of indication that the idea was transmitted to the group and also received by the group. A verbal remark made is by itself not sufficient proof of communication, as it does not provide an indication of being received by the other group members. A rough indicator of being received by the group members is provided by means of a representation present on the posted flipcharts, as, according to creative problem solving methodology, all ideas shared need to be represented on the flip-charts.

Based on an earlier operationalization of originality of ideas by Barron (1955), Stein (1974) defines creativity as 'novelty that is useful'. This leads to the second minimum requirement for ideas to be included in the link system. Ideas need to be - at least somewhat - related to the task at hand. They can be general directions for solutions, such as idea 11 in the sample brainstorming meeting (see table 3.2): 'things that make the same sound, but when you fit them into each other, it provides a different sound'. They can be far-fetched analogies or metaphorical descriptions, like idea 16 in the same meeting: 'both a mosquito in a cage'. They can be concrete solutions, like idea 15, 'wind chimes', or ideas for aspects of a solution, like idea 18
in the sample, ‘(mosquito in a cage)...in your ear...bzz!’”, which leaves the mosquito in a container idea intact, while adding to it a specific position on the body.

This provides a crude but -for now- sufficing formalization for the term ‘idea’. It is more difficult to provide a workable definition for the term ‘link’. Clearly a link signifies a connection between two ideas, signifying that the coming to existence of the latter of these two ideas can at least partly be contributed to the presence of the earlier idea. The smallest link system possible consists of one link and two ideas. To assist the discussion, the first idea generated is referred to as the ‘source idea’ and the later idea is referred to as the ‘resultant idea’ (see figure 3.8).

![Figure 3.8: Primary link system](image)

The linkography method is sensitive to the working definition of links. Link systems are notably different when solely direct connections between ideas are scored as links, compared to when indirect connections are considered to be links as well. The requirement for links as applied in this research project is that links need to point out a direct connection between ideas. For instance, in a link system between three ideas A, B and C, the presence of links between ideas A and B, and between ideas B and C, does not automatically mean that there is a link present between ideas A and C. A link between ideas A and C is only noted when idea C makes direct reference to idea A, or when there are other clues that support a direct connection between idea A and C (see figure 3.9).

![Figure 3.9: Links in a link system only based on direct connections](image)

In Goldschmidt’s approach, the sole criterion used for determining links between moves is ‘common sense’, which she defines by quoting an English dictionary as: "good sound ordinary sense" (Goldschmidt & Weil, 1998, p. 90). She mentions that this, in practice, means that: "...a link between two moves is established when the two moves pertain to the same, or closely related, subject matter(s)..." (p. 90). This working definition also includes many indirect connections, which render the linkographs in Goldschmidt’s research generally denser than the link matrices in this thesis.
For idea generation meetings Goldschmidt's working definition for links is not sufficient. In idea generation meetings other operational mechanisms for links are likely to be present, in addition to the similarities in subject matter. For instance, free associations are welcomed in idea generation meetings, which means that the earlier idea is used as a springboard towards a new direction for generating ideas. For example, the word 'ball' can relate to doing sports, which might lead to 'injury'. In this case, a link between 'ball' and 'injury' is present, even though the subject matter between these two ideas are not likely to be considered closely related when encountered separately.

Furthermore, the reliability of 'common sense' in determining links in idea generation meetings may be limited, especially when considering these ambiguous connections. We attempt to enhance the reliability by developing indicators for links, in order to provide judges with guidelines for scoring links in addition to detecting similarities in content, such as:

- Designers relating to earlier ideas when they verbalize their ideas. This can be found in the protocol, e.g. Diane reacts to Henri’s idea 7: 'ankle bells' with: 'Yes, something like a rattle'. This verbalization provides an idea (something like a rattle), but also a connector to the previous idea (Yes).
- Similarities in associations. For instance, idea 16 'both a mosquito in a cage' is linked to an earlier idea that proposes that partners carry live mice in their pockets. These ideas both refer to carrying live animals which have corresponding sounds.
- Resemblance in aspects of idea sketches (when applicable).
- Looking actions. For instance, a participant generates an idea after studying an earlier idea. Such indicators can be found by observing the videotape of the meeting.
- Gestures. For instance, when explaining idea 15 'wind chimes', Diane points at an idea generated during the preceding brainsketching step (see figure 3.10). She says: 'Those sorts of wind chimes that you both have in front of your house. If the wind blows it is as if the other person blows into the chimes'.

![Figure 3.10: Wind chime idea generated during the brainsketching step.](image)
These indicators cannot account for all the links that are recognized; common sense still has a role in assessing the links between ideas. But the indicators do assist in striving towards a more objective approach. The role of situational or context indicators, which are not related to the subject matter of the ideas, is further explored in section 6.4.

Applying linkography 3.5

Constructing a link matrix 3.5.1

The short brainstorming step in the design group meeting is used to explain and test the linkography approach. The videotape of the meeting was transcribed into a protocol. Fragments that contain separate ideas are identified. These fragments are then labeled in order to provide quick descriptions of the ideas. In this example this naming is not very crucial, as the verbalizations of the ideas are not very long. In other instances, when participants provide longer descriptions of ideas, or explain their idea sketches in detail, it is important to have quickly accessible titles for identifying chunks of information that constitute the ideas. This makes it possible to quickly evaluate the existence of connections, which is necessary, because the short brainstorming example with 27 ideas already provides 351 possibilities for links. For each of these possibilities a judgment of whether or not a link is present needs to be made. In the experimental meetings of this research, idea generation steps of over 60 ideas, requiring judges to make over 1770 judgements, are not exceptional. Obviously, it is impractical to keep reading and interpreting all the contents of the fragments for each judgment. A more workable approach is to first study the videotapes and the idea fragments in the protocol carefully and then use the fragment titles as the primary identifier for ideas in the link judging process, while re-examining the videotape in small steps. If difficulties are encountered, the full protocol text and, if applicable, sketches can be used for further clarification.

The brief idea descriptions are put into a matrix display, accompanied by their chronological numbers and identifiers for the originators of the ideas (in the example meeting, the designers are identified by fictional names corresponding to the letters D-I in the alphabet). This provides a table format suitable for making notations of the connections between ideas. In scoring the links, we followed Goldschmidt's method, by determining the backlinks. These are the links between idea at hand with previously generated ideas. For each idea the existence or non-existence of links with each of the earlier ideas is determined. For example, there are no indications whatsoever for links between idea 6, 'squeezable toy animals', and the four preceding ideas (ideas 2-5). However, idea 6 has a strong link with idea 1, 'carrying mice with the same sound'. The idea concretizes the notion of carrying live animals in your pocket, by substituting the live animal for a rubber squeaky toy.
Backlinks signify the path that leads to the generation of the idea. In the matrix display, backlinks are marked in the column above the idea (represented by the number in the diagonal box). Forelinks signify the present ideas’ impact on idea generation to come. Forelinks are marked in the row next to the idea. In contrast to Goldschmidt’s original linkograph display, which rotated the diagonal of the matrix into a horizontal position, the matrix format is preserved. In our opinion, the matrix is a more familiar type of display for researchers interested in analyzing link system. Besides, it is a particularly suitable format for digesting the data. Figure 3.11 shows the link matrix of the Timbuktu design team brainstorming step.

![Figure 3.11: Link matrix of the Timbuktu design team’s brainstorming step](image)

A link matrix provides a graphic overview of the structure of the linking process taking place in an idea generation meeting. For instance, in this sample most links are situated very close to the diagonal, which means that there is a lot of direct building on each other’s ideas, but there is little use of the knowledge generated earlier. The idea generation process appears to be dominated by a flow of instantaneous associations. Some other interesting link systems can be seen in this link matrix. Ideas 16 to 19 are fully interlinked with one another. In the link matrix this is seen as a black triangle on the diagonal of the matrix. Goldschmidt (1992) identifies such triangle-like structures as webs: “A web is formed when a large number of links is formed among a relatively small number of moves” (p.74).

Another link structure identified by Goldschmidt is the ‘sawtooth track’. This refers to a series of subsequent links on the diagonal, which according to Goldschmidt occurs: “when a designer builds one proposition upon another in a sequential order” (p.74-75). In terms of idea generation, a sawtooth track link system refers to an instantaneous association type of idea generation, meaning that each idea is a direct association to the previous idea. In the current link matrix, the links between ideas 21 to 25 constitute a sawtooth track link system. Idea 22, ‘earrings’ is a simplification of the ‘vibrating implant’ idea. Idea 23 adds to this earrings idea by adding the ‘caressing the neck’ feature. Idea 24 interprets the ‘caressing the neck’
feature as 'soft things hanging from the earrings'. Finally, idea 25 further concretizes the 'caressing the neck' feature by proposing 'toucan feathers' as an instantiation of 'soft things'.

To further clarify the method, we will first discuss a small sample of the link matrix, from ideas 16 to 25 (figure 3.12). Clearly, larger quantities of links need to be taken into account for the link descriptors presented below in order to be reliable. Their application on the example with ten links is solely intended for illustration. It is interesting to notice that sections of a link matrix can be considered autonomously. The sample between ideas 16 and 25 contains all there is to know about the linking between this sample of ideas. The fact that some ideas may have a strong input from ideas before idea 16 does not influence the linking within this sample as the matrix contains only internal references. This allows for dividing up and comparing sub-sections within one meeting, a feature of the linkography method which we make use of in the empirical research.

![Sample of the link matrix between ideas 16 and 25](image)

Within the sample, idea 22, 'earrings', has two backlinks, with ideas 21 and 19, and one forelink, with idea 23. The earrings idea is a direct reaction to the previous idea 21, 'vibrating implant'. With the earrings idea, designer Fred attempts to provide a strong simplification of the vibrating implant idea. Idea 22 also has a backlink with idea 19, 'earring with mosquito inside'. Designer Fred appears to refer to this earlier idea, as this idea introduced the general notion of earrings. Idea 22 is the basis for Diane's idea of 'earrings that caress your neck', which means that it has a forelink with this idea. It is interesting to notice that Fred's idea 20, 'cell phone subscription for partners' has neither backlinks nor forelinks. This means that in terms of linkography, this idea is independent of the other ideas in the sample.

So far, the link matrix allows for a general inspection of the type of 'building on each other's ideas' that is happening in the idea generation process. In order to be able to compare the link systems of various meetings, relative measurements are needed that allow for comparing link matrices from different meetings, regardless of the number of ideas generated.
3.5.2 Link density

The *link density* (LD) divides the total number of links in an area by the total number of ideas in that area. Consequently, the link density in our sample is:

\[ LD = \frac{13 \text{ [Number of links]}}{10 \text{ [Number of ideas]}} = 1.30 \]

Link density is a relative measure for the integratedness of the idea generation process. It provides an indicator for the way in which the 'seeking combinations' guideline for divergent thinking is followed. The total quantity of ideas generated is still relevant for assessing the idea generation process, but it is an indicator for a different guideline, namely, 'strive for quantity'. By introducing a relative measure, the total number of ideas generated does not influence the indicator for the 'seeking combinations' guideline.

3.5.3 Self-link index

Self-links are the links that designers make with their own ideas. Interpersonal links are links that designers make with each other's ideas. In a 'full' group situation, the designers build upon the generated ideas regardless of who conceived of them. The proportion of self-linking happening provides an indication of how much the actual process matches a 'full' group process. This proportion of self-linking is referred to as the Self-Link Index (SLI). A low Self-Link Index indicates a lot of building on each other's ideas, and therefore signifies a well-integrated group process. A high Self-Link Index indicates a high proportion of individual idea generation processes taking place in parallel, which is a sign of a poorly integrated group process. The hypothetical 'full' group situation is characterized by an idea generation process in which the group members make an equal number of connections with ideas from all the group members, including their own ideas. Then, a crude indicator for such a 'full' group process can be regarded to be a Self-Link Index that is smaller than or equal to, one divided by the number of group members:

\[ SLI_{\text{full group}} \leq \frac{1}{n_{\text{group members}}} \]

In the link matrix in figure 3.13, each link between persons is identified by first writing down the character for the originator of the resultant idea and then the character for the originator of the source idea. For example, The link between ideas 21 and 22 contains the characters 'FE', which means that Fred generated idea 22 by making use of Elly’s idea 21.
In the brainstorming step there are three self-links, namely the link between idea 6 and idea 1, between idea 11 and idea 3, and the link between idea 14 and idea 13. Coincidentally, Fred makes all of these self-links. In the sample there are three self-links and 28 interpersonal links, which provides a Self-Link Index of 0.10. This means that in terms of self linking, the brainstorming step easily matches the requirement for the full group situation, which for this group of six designers is determined by a Self Link Index of 1/6 (0.17) or lower.

**Link type indices**

Along with the overall number of ideas, the link density, and the self-link index, the types of links made are of interest, because they say something about the type of idea generation process that is taking place. Grysiewicz (1980) categorized ideas in idea generation meetings according to the ways in which they relate to the problem. In his research, he used a typical re-design assignment: *What else can be packed in a tea bag?* He then looked at the relationship between the existing product and the new idea. He developed four supposedly distinct categories reflecting the adaptor-innovator construct developed by Kirton (for the original publication of the instrument, see Kirton, 1979; for a more comprehensive overview, see Kirton 1989): 1) Direct: Solution answers the question. The solution does not require any modification and stays well within the constraints of the problem as given; 2) Supplementary: Solution involves a new use for the product where product content and product function interact; 3) Modify: Solution involves a structural change; and 4) Tangential: Solution involves different functions for materials used in the construction of the product.

In contrast to Grysiewicz, a local perspective is taken by examining the characteristics of the transformation that takes place between the former and latter idea in a link. However, the relationship between ideas in a link can still be described by the categorization mentioned. Category 1 (direct) is dropped, as this
category does not refer to the transformation that occurs between ideas in a problem-solving process. It solely refers to the problem-solution relationship. This leads to the following three link categories (examples are taken from the brainstorming sample, see table 3.2):

- **Supplementary (S)**: Small and auxiliary change. The relationship between ideas is based on minor improvements on the same general idea. For instance, the link between idea 23 and idea 24 is supplementary. Idea 23 consists of ‘An earring that caresses your neck’. Idea 24 provides an option for the neck-caressing feature of idea 23: ‘(An earring that caresses your neck)... with soft things hanging from it’. Idea 24 is not different from idea 23; it is a mere refinement of that idea.

- **Modification (M)**: A modification link provides structural changes in the idea, while maintaining the existing line of thought. Some major aspects of the former idea are still present in the latter idea. For example, idea 5, ‘Castanets with corresponding sounds’ and idea 7, ‘Ankle bells’ have a modification relationship. The two ideas are different from each other, but they share the same line of thought, namely something with simple musical instruments.

- **Tangential (T)**: Even though there are indications for a link, there is no direct function of the earlier idea present in the current idea. Most tangential links are based on free association (Osborn, 1953). For instance, there is a tangential link between idea 21 and idea 18. Idea 18, ‘(a mosquito in a cage or tube) in your ear’, functions as a springboard for idea 21, a ‘vibrating implant’. All the functions in these two ideas are different. The buzzing sensation of the mosquito in the ear spurs an entirely different application of vibration in the later idea. Usually there is little resemblance in the subject matter of the ideas that have a tangential link, which makes situational indicators, like gestures, especially important for determining these links.

Application of this division in link types to our sample gives the following picture (figure 3.14):

![Figure 3.14: Link types in the brainstorming sample](image)

72
We will discuss a sample of the link matrix, between ideas 1 and 14, to provide some insight into the way in which the link type for each link was determined, see table 3.3:

<table>
<thead>
<tr>
<th>Resultant idea</th>
<th>Source idea</th>
<th>Description link type</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Castanets with corresponding sounds</td>
<td>3 Tuning forks with the same tone that resonate</td>
<td>Modification - The castanets are a variation of instruments with related sounds</td>
</tr>
<tr>
<td>5 Castanets with corresponding sounds</td>
<td>4 Drums</td>
<td>Modification - The castanets are a variation of basic musical instruments</td>
</tr>
<tr>
<td>6 Squeezable toy animals</td>
<td>1 Carrying mice with same sound (squeeze, eep)</td>
<td>Modification - The live mice in idea 1 are replaced by toy animals</td>
</tr>
<tr>
<td>7 Ankle bells</td>
<td>5 Castanets with corresponding sounds</td>
<td>Modification - The ankle bells are a variation of gypsy-like musical instruments</td>
</tr>
<tr>
<td>8 Rattle</td>
<td>7 Ankle bells</td>
<td>Supplementary - The ankle bell idea was also described as a rattle when designer H mentioned this idea. Designer D repeats the rattle idea to make it explicit</td>
</tr>
<tr>
<td>9 Tinkerbell</td>
<td>7 Ankle bells</td>
<td>Supplementary - Tinkerbell is a name given to the ankle bells idea; it does not provide an alternative idea</td>
</tr>
<tr>
<td>10 Little bell as pendant</td>
<td>7 Ankle bells</td>
<td>Modification - A variation on the carrying bells idea</td>
</tr>
<tr>
<td>10 Little bell as pendant</td>
<td>9 Tinkerbell</td>
<td>Modification - A variation on the carrying bells idea. The name ‘tinkerbell’ may have spurred the idea of carrying a little tingling bell. Therefore both ideas 7 and 9 are included as links</td>
</tr>
<tr>
<td>11 Something that makes the same sound, fitting into each other provides different sound</td>
<td>3 Tuning forks with the same tone that resonate</td>
<td>Tangential - The corresponding sounds are used as a springboard towards an entirely new idea of fitting two sound-making objects into each other to provide a new sound</td>
</tr>
<tr>
<td>11 Something that makes the same sound, fitting into each other provides different sound</td>
<td>5 Castanets with corresponding sounds</td>
<td>Tangential - The corresponding sounds of the castanets are used as a springboard towards an entirely new idea of fitting two sound-making objects into each other to provide a new sound</td>
</tr>
<tr>
<td>12 One carries a doorbell, the other a button</td>
<td>11 Something that makes the same sound, fitting into each other provides different sound</td>
<td>Tangential - The products that fit into each other to make a new sound functions as a springboard to start free association regarding things that belong together</td>
</tr>
<tr>
<td>13 Corsage for formal party ... one person wears computer mouse, the other a mouse trap</td>
<td>12 One carries a doorbell, the other a button</td>
<td>Modification - Further association of things that belong together</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>&gt; 14 Plug and outlet</td>
<td>12 One carries a doorbell, the other a button</td>
<td>Modification – Further association of things that belong together … electricity related</td>
</tr>
<tr>
<td>14 Plug and outlet</td>
<td>13 Corsage for formal party ... one person wears computer mouse, the other a mouse trap</td>
<td>Modification – Further association of things that belong together … corsage for formal party related</td>
</tr>
</tbody>
</table>

This division into link types is still somewhat ambiguous. As the three link types are segments of the same adaptor-innovator scale, there are bound to be difficulties at the borders of the types, between supplementary and modification, and between modification and tangential. For instance, idea 13, ‘corsage for formal party’ and idea 14, ‘plug and outlet’, have very little in common, which would suggest a tangential-type link. But at the same time, the ideas are both direct variations of the search direction of things that belong together, which suggests a modification-type link. In this case, the latter argument was given prevalence because the same designer mentioned both ideas shortly after each other, which suggests that they are both explorations of the same line of thought.

A different type of ambiguity in this sample is provided by the link between idea 9, ‘tinkerbell’, and idea 10, ‘little bell as pendant’. As the ‘tinkerbell’ idea provides a name for the ‘rattle’ idea (idea 8), the link between ideas 9 and 10 is the same as the link between ideas 8 and 10, namely a modification. On the other hand, the name ‘tinkerbell’ may have provided the image of the fairy in Peter Pan who has this name. This may have functioned as a springboard for coming up with a little companion that makes a tingling sound, in this case a pendant with a little bell. Here the first argument was given prevalence, as the latter might be too far-fetched.

Developing more thorough guidelines may reduce the ambiguity of the link types. However, it is not likely that this ambiguity can be entirely eliminated. The link types in the extremes of the scale -the supplementary and the tangential links- are therefore most informative.

Again, a relative indication of the types of linking in the process is needed in order to allow for comparing between meetings or sections of meetings. These are the link type indices (LTI): The number of links of a certain type, divided by the overall number of links in a link matrix. In this sample of 30 links, 10 links were marked as supplementary links, 15 as modification links and 5 as tangential links, which provides the following link type indices:

- Supplementary: \( LTI_S = \frac{10}{30} = 0.33 \)
- Modification: \( LTI_M = \frac{15}{30} = 0.50 \)
- Tangential: \( LTI_T = \frac{5}{30} = 0.17 \)
The link type index is a measurement of the effects of the creative problem technique on the process. A high LTIₜ signifies a process that is rich in novel combinations. It does not necessarily mean a ‘good’ problem solving process. This depends on the task at hand (Grzybowski, 1987). Typically, a high level of novel insights is needed during early idea generation because this helps the group to step beyond obvious ideas. In the later steps of the idea generation process, there is a need for developing ideas. Then, a high LTIₜ signifies a high amount of distraction in the process. In these later steps of the idea generation process a relatively high LTIₛ may indicate thorough idea development by building on other ideas within an accomplished frame.

Reliability of linkography 3.6

Introduction 3.6.1

As mentioned earlier, some critical remarks have been made of Goldschmidt's linkography approach as a method for analyzing design activity (see section 3.3). One of these related to the subjectivity of the coding system, due to Goldschmidt depending on the 'common sense' of outside judges for assessing links between design moves. Five types of indicators have been identified that may help judges to determine whether there is a link present between two ideas (see section 3.4). With these indicators we attempt to move beyond common sense as the primary judging tool. We realize that these indicators provide a mere starting point and throughout the empirical research we will attempt to reinforce them.

This section deals with strengthening the reliability of the general linkography approach. First, by assessing the agreement between independent judges for the brainstorming step that has been used as an example in this chapter. Secondly, by exploring whether the participants themselves are able to provide reliable link matrices of the process, soon after finishing the meeting. If this were possible, constructing link matrices could be included as part of the experimental meetings, which would avoid subjective interpretation of linking done by raters who were not involved in the idea generation process themselves.

Inter rater agreement 3.6.2

The link matrix is the basic result of the linkography approach, which is then used for further analysis by determining various link indicators. As the link matrix of a meeting forms the basic foundation on which all further analysis is grounded, the reliability of the link matrix is especially important. The reliability of the linkography approach was assessed by comparing the link matrices of the brainstorming sample that were produced by the researcher with those produced by the two independent judges.
The least complicated method for determining the agreement between two raters is to determine their proportion of agreement, found by dividing the number of decision moments that are agreed on by the total number of decision moments. In linkography, the total number of decision moments consists of all the positions within the upper triangle of the link matrix. For the brainstorming sample of only 27 ideas, there are in total 351 decision moments. For each of these decision moments a rater determines whether a link is present or not. The number of decision moments that are agreed on consist of the number of decision moments where both raters marked a link, added to the number of decision moments where both raters did not mark a link. This leads to very high proportions of agreement, which lack discriminative value.

This becomes clear as we consider the link matrices constructed for the brainstorming sample by two independent judges. Each judge was asked to thoroughly examine the videotape, and then fill out the link matrix while making use of the link indicators as much as possible. The judges first watched the videotape, and then went back through it again in small steps, while marking links on the link matrix. The judges were provided with the protocol and a transcription of the flipcharts from the brainstorming session. These documents were used regularly by the judges while determining the linking. This resulted in the following three link matrices made by the researcher (figure 3.15) and by the external judges (figures 3.16 and 3.17):

<table>
<thead>
<tr>
<th>Brainstorming</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></td>
<td>F</td>
<td>G</td>
<td>H</td>
<td>I</td>
<td>J</td>
<td>K</td>
<td>L</td>
<td>M</td>
</tr>
<tr>
<td>1. Carrying case with same sound (sequence, etc.)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2. Wine (Chinese,虽然 language)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3. Frying lips with same time that resembles</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4. Drums</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>5. Emergency with corresponding sounds</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>6. Squidfish by animal</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>7. Area unit</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>8. Resists</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>9. F. Trotted</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>10. Little kid as animal</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>11. Something that means same sound, living too far from each other prevents different sound</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>12. A rope serving a dual role, the other a button</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>13. D. Design of a complex, the other a complex</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>14. F. Plug and socket</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>15. G. Foreigner</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>16. L. Both a mosquito in a cage</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>17. P. It is a good joke</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>18. H. In your ear</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>19. D. An arrow with a mosquito inside</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>20. F. Estab's substitution for partner</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>21. E. Wearing ring</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>22. F. Earings</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>23. D. Earned from common by hand</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>24. C. With smell hanging from it</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>25. I. Toucan leather</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>26. G. Leather and nails</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>27. F. The two farmers met and said</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure 3.15: Link matrix of researcher (identical to fig. 3.11)
At this stage, the number of agreements and disagreements between links can be counted for each pair of link matrices, which are displayed in a so-called ‘confusion matrix’ (Robson, 1993, p.221), see table 3.4:

The confusion matrix displays the numbers of times that both raters agree, that both disagree, and the number of times that rater one marks a link, while rater two does not and vice versa. The two observers both mark links for 13 decision moments. They both do not mark links for 325 decision moments. In 9 decision moments, rater one marks a link while rater two does not, and in 4 decision moments, rater two marks a link while rater one does not.

An often-used measure of agreement in protocol analysis of design activity is the proportion of agreement. However, because link matrices consist of a small number of marked links in comparison to the total amount of link locations, the number of agreed ‘no link’ decisions will be very high. This will lead to high, but not very informative, proportions of agreement. A more refined measure for inter rater agreement is Cohen’s Kappa (Cohen, 1977). This measure is most often applied for determining the reliability when coding on a nominal scale with various categories.
Fleiss (1981) points out how Cohen’s Kappa can also be applied to determine the inter-rater agreement within a single category, which is the case in linkography. Cohen’s Kappa compensates the proportion of agreement for the chance of accidental agreement. Due to the nature of the idea generation process, generally very high proportions of negative decisions on links are found in linkography. This means that the probability that both raters agree on the negative links is very high. Cohen’s Kappa compensates for this with the following formula:

\[ K = \frac{(P_o - P_c)}{(1 - P_c)} \]

where:
- \( P_o = \) Proportion of agreement
- \( P_c = \) Proportion due to chance

Fleiss simplified this into the following formula for determining the inter-rater agreement within a single category. Assume the following general confusion matrix for two raters and one category (table 3.5).

\[ K = 2 \frac{(ad - bc)}{p_1q_2 + p_2q_1} \]

For the agreement between judge one and judge two this means that:

\[ K = 2 \frac{(13 \times 325 - 4 \times 9)}{(17 \times 329 + 22 \times 334)} = 0.65 \]

Fleiss (1981) provides a commonly applied classification regarding the required magnitude of Kappa in order to consider the agreement between judges to be adequate. He considers Kappa values below 0.4 to signify poor agreement. Kappa values between 0.4 and 0.6 indicate a fair level of agreement, between 0.6 and 0.75 indicates a high level of agreement and anything beyond 0.75 indicates an excellent level of agreement between judges. Landis & Koch (1977) also propose a classification, which is slightly less critical (see table 3.6). Note that the value of Kappa can be lower than one. This happens when the proportion of agreement between two raters is lower than the proportion of agreement due to chance.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.00</td>
<td>Poor</td>
<td>&lt; 0.00</td>
<td>Poor</td>
</tr>
<tr>
<td>0.00 - 0.20</td>
<td>Slight</td>
<td>0.00 - 0.20</td>
<td>Slight</td>
</tr>
<tr>
<td>0.41 - 0.60</td>
<td>Fair</td>
<td>0.21 - 0.40</td>
<td>Fair</td>
</tr>
<tr>
<td>0.61 - 0.75</td>
<td>High</td>
<td>0.41 - 0.60</td>
<td>Moderate</td>
</tr>
<tr>
<td>0.76 - 1.00</td>
<td>Excellent</td>
<td>0.61 - 0.80</td>
<td>Substantial</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.81 - 1.00</td>
<td>Almost perfect</td>
</tr>
</tbody>
</table>

Table 3.6: Classifications of Kappa values for inter-rater agreement
The value of $K = 0.65$ for the link matrices of the brainstorming sample as produced by raters one and two indicates a ‘high’ level of agreement between the two independent raters according to Fleiss, and a ‘substantial’ level of agreement according to Landis & Koch.

Cohen’s Kappa was also calculated for the agreement between each of the independent judges and the researcher. The Kappa for the agreement between the researcher and the first rater is $K = 0.63$ and the agreement between the researcher and the second rater is $K = 0.57$. These levels of agreement are acceptable, but they also indicate room for improvement. A stronger procedure for assessing links will be developed based on the experiences gained with applying linkography to analyze the experimental idea generation meetings.

One critical remark needs to be made regarding the procedure for scoring links. Raters were asked to determine for each combination of two ideas whether a link was present or not. However, for practical considerations -such as reducing the time required for raters to fill out a link matrix- they were only asked to make marks in the link matrix for links present, not for the absence of links. This may have had a slight influence on the link matrices.

After determining the links in a link matrix, the categorization of the links into three types (supplementary, modification, tangential) is a step of further data analysis that is open to interpretation. The reliability of this further categorization was only briefly explored. One independent rater determined the link types of the brainstorming section, which resulted in a ‘poor’ rate of agreement ($K = 0.38$). The low Kappa value can be explained by the fact that the Link Type Index is not actually a categorical measure, for which Cohen’s Kappa is an appropriate measure of agreement. Instead, the link types represent three areas of a spectrum of linking, based on Kirton’s (1989) Adaptiveness-Innovativeness scale. This leads to ambiguities at the perimeters of the link types, as mentioned in the previous section (3.5). In that section, we discussed the motivation for deciding on link types for the links in part of the sample brainstorming meeting, to at least provide some insight into the ways in which the link types were determined. Further development of the guidelines for determining the link types may reduce ambiguity in the link type categorization.

**The group members as link raters?**

An intuitive answer to the question of who has the best insight into the CPS process that took place, is bound to be: ‘the participants themselves’. However, the literature on design research and cognition suggests that participants, when asked to re-call their process of idea development, tend to re-invent the process rather than re-call what actually happened. (see Dewey, 1896 for a seminal account; and see Gero, 1999 for providing consequences for design research). As an illustration of this tendency, in one of the later experiments, participants were asked to identify some
of the most interesting or surprising associations that they made during the idea generation process. They repeatedly identified connections that were physically impossible, because the acclaimed source idea was generated later in time than the resultant idea in the link mentioned by the designers (Chapter Five reports this empirical study).

In order to explore whether the group members themselves can provide reliable link matrices, the participants in the brainstorming meeting were asked to fill out link matrices of the brainstorming sample the morning after the meeting. For practical reasons, unlike the independent judges, the participants did not study the videotape of their meeting while filling out the link matrices. However, they were provided with the protocol text and the flipcharts of the meetings were posted on the wall, so that they could refer back to them. Five of the six participating designers filled out the link matrix.

The basic assumption made is that the participants can be considered reliable at determining the linking in the meeting when their link matrices have good levels of agreement with each other, and with the link matrices of the independent judges and the researcher. The average agreements between the various raters are depicted in figure 3.18:

![Figure 3.18: Agreement levels between raters](image)

The levels of agreement between participants range from ‘poor’ to ‘fair’ ($\chi = 0.37$, $SD = 0.08$). The levels of agreement between the participants and the two independent judges also range from ‘poor’ to ‘fair’ ($\chi = 0.44$, $SD = 0.11$). The levels of agreement between the participants and the researcher range from ‘fair’ to ‘good’ ($\chi = 0.54$, $SD = 0.08$). The level of agreement between the two outside judges is high (0.65) and the level of agreement between the two outside judges and the researcher is ‘fair’ ($\chi = 0.60$, $SD = 0.03$).

The participants have a very low level of internal agreement, which dismisses them as appropriate raters for determining links between ideas. The two independent judges have a high internal level of agreement and an acceptable level of agreement with the researcher, but the agreement between external judges and participants is lacking. The researcher has acceptable levels of agreement with both the participants and the independent judges, which suggests that he is an
appropriate person for determining the linking in the idea generation meetings. Then, link matrices constructed by independent judges can be used to verify the reliability of the researcher’s link matrix by means of determining the inter-rater agreement.

Summary

3.7

In this chapter we discussed the need for taking a process perspective, rather than an outcomes perspective for examining the data in this research project. The content perspective is the norm of past and present research into CPS meetings, dealing with the quantity and/or the quality of the ideas generated. We proposed that, if idea generation is a search process, it is more informative to investigate the qualities of the search process, rather than the outcomes of that search process.

Within the field of creativity research we were not able to uncover any research methods for analyzing the structure of the idea generation process. Within the adjacent field of design research, linkography (e.g. Goldschmidt, 1996) was detected as a method that specifically focuses on the structure of the problem solving process. Goldschmidt used linkography for assessing the productivity of design activity by determining the linking between design moves taking place. Linkography was further developed as a method for assessing the idea generation process by means of investigating the connections between ideas made in the idea generation process. Linkography was adapted and developed by studying links between ‘ideas’ rather than ‘design moves’ and by providing some basic indicators for links. In addition to this, various ways of further processing the data found within a link matrix were proposed, such as the link density, the self-link index, and the link type indices.

The researcher was found to be an appropriate rater for determining the linking between ideas in idea generation meetings. As a means of further improving the reliability of the linkography approach, Cohen’s Kappas will be used when analyzing the experimental meetings, to check the agreement between the researcher’s link matrix and the link matrices of independent judges.

To answer the research question, the adaptation to linkography made provides a suitable method for describing the structure of idea generation processes, which is the basis needed for making inferences about the functions of sketching in idea generation meetings.
Notes:

1 Unlike De Bono, we do not regard this as a criticism to the brainstorming technique; some military equipment is highly effective by using a 'scatter-gun approach, like the 'Goalkeeper' missile defense system, which, when activated, produces a virtual wall of bullets to protect marine vessels against incoming missiles.

2 Brankamp (1971) first used the term 'search area'. According to Buijs & Valkenburg (2000), a search is a "vivid picture of future company activities that comes into existence by combining the strategic strengths with interesting external opportunities" (p. 398, translated from Dutch).
Exploring the compatibility of the processes of brainstorming and idea sketching

Introduction

The first objective of this exploratory experiment which uses three adaptations of the brainstorming technique that include sketching in various ways, is to investigate whether the process of sketching is compatible with associative idea generation techniques, of which brainstorming is the most broadly known example. As was mentioned earlier (see section 1.4 and the foreword), this research project was initiated based on the notion that sketching could amplify brainstorming meetings in product design, as both sketching and brainstorming are said to function as tools for enhancing creativity in design. However, this notion is based on the assumption that the two tools are compatible. The tools are not compatible if including sketching in the brainstorming technique degrades the structure of the idea generation process. Then, their supposed functioning cannot be superimposed. If this is the case, combining sketching and brainstorming does not necessarily provide a better idea generation technique. Instead, it provides a structurally different idea generation technique.

To investigate the validity of this assumption, an additional research question is introduced: Are the processes of brainstorming and idea sketching compatible?

To be compatible, sketching needs to enhance, or at least not deteriorate the functioning of the brainstorming technique. Whether or not this is the case can be examined by assessing the extent to which variations to brainstorming that include sketching meet the four guidelines to divergent thinking (see section 1.2).

The answer to this question will have strong implications for the further research direction of this thesis. If, based on the empirical data in this exploratory study, the question is answered affirmatively, then the remainder of the research can be directed towards developing and testing idea generation techniques that include sketching. If the question is answered negatively, then further empirical research needs to be directed towards acquiring a better understanding of the nature of the structural differences between idea generation techniques that use written language-like brainstorming- or sketching as means for expressing ideas.

The second objective of this study involves exploring various ways in which sketching could be included in the brainstorming technique. In Chapter One, we noted that very few idea generation techniques that include visual expression were encountered in the creative problem solving literature (see section 1.4). The two idea generation techniques that were found, the 'Gallery method' and
'Brainsketching' both involve sketching ideas individually, alternated with distinct moments for exchanging ideas. Sketching in these techniques appears to be used in support of the creative processes of the individual group members. The primary interest for the current study involves exploring ways in which sketching may be used as a tool for enhancing the group's idea generation process. This leads to the second question to be answered in this exploratory study, corresponding with the first main research question of this thesis:

RQ 1: How do various ways of including sketching in idea generation meetings influence the group's idea generation process?

4.2 Experimental meetings with graphic variations of the brainstorming technique

4.2.1 Introduction
This exploratory research project consisted of four meetings, three experimental idea generation meetings and one control group meeting. At the time of these meetings, we were looking for a broad range of ways in which sketching could be included in idea generation meetings. We had not yet limited the search to the role of sketching in associative idea generation techniques. Therefore, the meetings were designed to simulate a full creative problem solving meeting in which all three components of the creative problem solving process -Finding the Problem, Generating Ideas, and Planning for Action- were represented (see section 1.2). This allowed for exploring various techniques that include sketching in the different components of the creative problem solving model. This chapter focuses on an early idea generation step in the experimental meetings, in which various ways of combining sketching and brainstorming were explored (see table 4.1 for an overview of the entire meeting plan).

4.2.2 Experimental set-up
The four meetings were held in the same location and were guided by the researcher, who is an experienced creative problem solving facilitator. Meetings A and B were held first. Meeting C and control group meeting D were held a few weeks later. The researcher strictly observed the creative problem solving method rules and guidelines for facilitating idea generation meetings (Isaksen et al, 1994), unless mentioned otherwise. Following the creative problem solving method, ideas were recorded on flipcharts that were then posted on the wall. For two of the techniques, the designers sketched their own ideas. For this purpose, each designer had been assigned a specific marker color and a set of pre-numbered sheets of paper. These sheets were pasted onto the flipcharts by the facilitator to make them available to the group. After each meeting the process was discussed with the designers. The meetings were recorded on videotapes, which were then transcribed into protocols.
For this study a design task developed and applied by Dorst (1997) and Christiaans (1992) was used. The designers were asked to generate ideas for a new litter disposal system for a new Dutch railway carriage. This design task, and possible routes of solutions, has been thoroughly scrutinized by Dorst in his research. The litter disposal system assignment is, according to Dorst: "Challenging, realistic, appropriate for the subjects, not too large, feasible in the time available, and within the sphere of knowledge of the researchers" (p. 91-92). This assignment is typical for product design, as it requires the integration of a number of aspects, such as ergonomics, engineering, form giving and aesthetics, and business (Christiaans, 1992).

To make this assignment suitable for application in idea generation meetings, we limited the amount of background information available to the group members and streamlined the assignment itself into a brief problem statement: 'How to make a new litter disposal system for Dutch railway trains?' This statement was placed on a flipchart in the front of the room, accompanied by some of the key information, as suggested by creative problem solving methodology (Isaksen, Dorval, & Treffinger, 1994). On another flipchart, sketches of the present and new interior of the train were posted, along with some of the main dimensions.

In the beginning of each meeting, the assignment was introduced and briefly discussed, along with the key information, such as the present waste system used, an existing alternative, and the types of waste found in the bins.

Each group consisted of four designers, which means that, in total, sixteen designers participated. These were fourth or fifth year product design students who were involved in a course in facilitating creative problem solving meetings. The advised group size in creative problem solving meetings varies between five and seven participants. In this study, we decided on meetings with only four participating designers in order to keep the group process clear and observable. The group members were expected to be very fluent in the idea generation process. They were engaged in a course in creative problem solving and thus accustomed to working together and trained in applying creative problem solving techniques. All participating designers had sufficient skill levels in designing and drawing.

The four meetings shared a general session plan with a total duration of about two hours. Within this general plan, the application of idea generation tools was varied in order to explore various ways in which sketching can be included within the various components of the creative problem solving framework. The general meeting plan consisted of the following steps (Table 4.1):

**Task**

**Participants**

**Process**
Table 4.1: Process plan of the idea generation meetings

<table>
<thead>
<tr>
<th>Step</th>
<th>Time (min)</th>
<th>CPS component</th>
<th>Meeting plan:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00-0.15</td>
<td>n/a</td>
<td>Warm-up activity and briefing on the problem</td>
</tr>
<tr>
<td>2</td>
<td>0.15-0.35</td>
<td>Generating Ideas</td>
<td>Generating ideas through brainstorming variations. (Selecting ideas together with ideas generated in step 5)</td>
</tr>
<tr>
<td>3</td>
<td>0.35-0.55</td>
<td>Finding the Problem</td>
<td>Data finding Selecting relevant data</td>
</tr>
<tr>
<td>4</td>
<td>0.55-1.10</td>
<td>Finding the Problem</td>
<td>Generating alternative problem statements Selecting and compressing problem statements</td>
</tr>
<tr>
<td>5</td>
<td>1.10-1.30</td>
<td>Generating Ideas</td>
<td>Generating ideas through creative confrontation technique Selecting ideas</td>
</tr>
<tr>
<td>6</td>
<td>1.30-1.50</td>
<td>Planning for Action</td>
<td>Developing ideas through brainwriting variations (Selecting ideas, if applicable)</td>
</tr>
<tr>
<td>7</td>
<td>1.50-2.00</td>
<td>n/a</td>
<td>Group discussion</td>
</tr>
</tbody>
</table>

The experiment consisted of a full CPS meeting, including a warm-up activity and problem introduction, followed by an initial round of generating ideas through variations of the brainstorming technique. Then a stage of problem finding, followed by further idea generation through graphic variations of an existing creative confrontation technique (Visually Identified Relationships, see Isaksen et al, 1998), and finally a step of idea development through graphic variations of the brainwriting technique. In the group discussion, positive and negative experiences of the participants were discussed for each meeting step.

In order to explore various combinations of sketching and brainstorming in idea generation meetings, we limit the analysis to step two, the first idea generation step. This first idea generation step is free of interaction effects (variations in idea generation techniques introduced in earlier steps of the meeting may influence the process of the techniques applied in the following steps). Step two helps explore the functioning of graphic variations of the brainstorming technique and whether sketching supports the associative idea generation process. In this step, the design groups generated ideas for approximately twenty minutes, or until the flow of ideas stopped.

4.2.3 The graphic variations to brainstorming applied

In the meetings, graphic alternatives to the brainstorming technique are introduced. The effects of these variations on the amount and types of linking between ideas are explored. The working medium in meetings A and B is purely graphic, with the distinction that in meeting A a graphic facilitator takes care of recording the options and in meeting B the designers sketch their own ideas. The experiences with
the graphic variations in meeting A and B lead to an alternative graphic variation to brainstorming that combines the working media of writing and sketching. This hybrid technique was applied in meeting C. Meeting D functions as a control condition. In this meeting, regular brainstorming is applied, which is based on written language as a working medium. A brief description of the applied tools is provided below:

- **Regular brainstorming (Osborn, 1953).** The divergent step consists entirely of idea generation in words. Group members speak their ideas out loud and the facilitator writes down the ideas on the flip chart.

- **Brainstorming with graphic facilitator.** A graphic facilitator captures the problem solving process in pictures rather than in words, thus providing a ‘collective graphic memory’ for the designers (McKim, 1972; Lakin, 1988). The graphic facilitator works in cooperation with a process facilitator. So, apart from the group members, two facilitators are present in this meeting. Graphic facilitation is mostly used in organizational change and problem mediation (Ball, 1998). Application in a creative problem solving context is less common. The graphic facilitator technique can be considered the most literal graphic variation to brainstorming made. The only difference between regular brainstorming and the graphic facilitator technique is that the facilitator makes notations of ideas in sketches instead of written words.

- **Visual brainstorming.** This is a graphic adaptation of the Brainstorming with Post-its technique (Isaksen et al, 1994), in which the participants speak their ideas out loud, and write their ideas down on separate post-it notes in a concise and legible manner. During visual brainstorming, rather than writing them down, the designers make sketches of their ideas on individual sheets of paper (or jumbo-sized post-it notes). When ideas are captured, the designers give the sheets to the facilitator who then pastes them on a flipchart. Visual brainstorming is the closest possible adaptation to the brainstorming technique in which the participants themselves sketch their ideas.

- **Brainstorming with sketches added.** This technique was developed based on the limitations encountered for the fully graphic variations to brainstorming applied (see section 4.4). Instead of requiring sketches, here ideas are generated following the regular brainstorming principles. The facilitator writes down ideas on a flip chart, but the designers are invited to also sketch their ideas on individual sheets, in order to help illustrate and enrich the written ideas. The facilitator then pastes the idea sketches next to the written notation on the flipchart. This technique aims to allow for better access to the group’s earlier ideas.
The idea generation techniques vary both in the person who did the recording: participants, facilitator or both, and in the applied medium of recording: sketches, written language, or a combination of both (see table 4.2). The principal comparisons to be made are between traditional brainstorming and the two fully graphic variations. As mentioned before, the ‘brainstorming with added sketches’ technique was developed based on the experiences with the fully graphic techniques in meeting A and B. It will be interesting to compare this technique to both regular brainstorming and the graphic techniques.

### 4.3 Applying linkography to the experimental meetings

#### 4.3.1 Constructing link matrices

The videotape of each meeting was transcribed into a protocol. In the protocol, the participating designers were identified by fictional names, corresponding to the letters in the alphabet. Related sketches were pasted into the protocol at the location in which the idea came up. All fragments of text that could be appointed to single ideas were selected. Each fragment was given a title that briefly described the idea, for example, idea 49 in meeting C. The verbalizations made by the group in relation to this idea and the idea sketch are provided below (fig. 4.1):

**Figure 4.1: Meeting C, idea 49: 'Water flowing in trash bins'**

<table>
<thead>
<tr>
<th>M:</th>
<th>Look, here I sketched two waste bins, which lead to a reservoir [points to idea sketch]</th>
</tr>
</thead>
<tbody>
<tr>
<td>K:</td>
<td>With water</td>
</tr>
<tr>
<td>M:</td>
<td>With water, whatever... This is the reservoir and the deal is that the cleaning person does not really have to clean the bins, instead he stands at the platform and empties the units, empty them each time.</td>
</tr>
<tr>
<td>Facilitator:</td>
<td>So, if I see it correctly that is some kind of a trash bin toilet?</td>
</tr>
<tr>
<td>M:</td>
<td>Yes, with some kind of a flushing system with drainage to clean that... in any case, the cleaning does not happen inside the train but outside the train.</td>
</tr>
</tbody>
</table>
At this point in the process ideas were generated by the designers and recorded by
the facilitator. The designers were invited to provide sketches if they so desired.
Designer M explains his idea sketch to the group. He then reacts to the remark made
by designer K and while explaining his idea. The facilitator then attempts to
paraphrase designer M's idea in order to condense it so that he can write it down
on the flip chart: 'Flushing towards reservoir when full'. The label given to this idea by the researcher is 'Water flowing in trash bins'. Below, the idea fragments from the protocol of meeting C are displayed (table
4.3).

<table>
<thead>
<tr>
<th>Idea/Label</th>
<th>Protocol text</th>
</tr>
</thead>
</table>
| 1/K
Newspaper tray on ground |
| K: Well, I was thinking about those newspapers...that you can place a newspaper tray on the right-hand corner on the ground; in which people can leave their newspapers. Just a tray for old newspapers which is very handy for many people...that when you go home at night, then... |
| L: Of course...recycling newspapers. |
| K: ...yes...that if there is a newspaper in the tram, then I take it with me to read it. And, when you have a tray like that...Firstly, then they are stacked away, secondly, you can see if there is something fun to read and thirdly, the Dutch railways can start to recycle paper...(0:15) And then the waste bins and garbage bags do not fill up so much. |
| 2/L
Double trays for paper and general waste |
| L: I was thinking about a double waste tray with general waste on one side, and newspapers on the other side. |
| 3/A
Pedal for opening gives access to central waste container |
| L: I was thinking that you can open with a foot pedal so that you don't have to grab the dirty thing...that your trash then ends up somewhere under the floor in a big container that you can empty. |
| 4/L
(Central waste container) can be emptied from outside |
| L: That you can perhaps even empty from the outside or something. |
| 5/A
(...can be emptied from outside...) and cleaned with a hose...and separate paper holder |
| L: (0:16) Yes, perhaps you can empty it from the outside, at the side of the wagon and then connect a hose to it and rinse. |
| Facilitator: A trash reservoir under the floor or something? |
| L: Yes, so no trash bins at all...and perhaps a separate newspaper holder or something. |
| 6/M
Separating garbage |
| M: I was thinking to have the trash separated. People at home do that too...that should happen if they are in the train too, basically, because it is not unfamiliar anymore...I do not have a nice picture of that yet, but they... |
| 7 A
Shredder |
| L: A shredder. |
| 8/M
Mailbox for paper |
<p>| M: Yes, some kind of a mailbox in which people can just stick their paper. |
| 9/L | Mailbox under seats | L: Yes, I was just thinking about a mailbox under the seat or something... because there is still quite some space. |
| 10/K | Mailbox in fold-away table | K: I think that one is very nice. And that you... I think it is very easy to... the table is really too small, and the trash bin is too close to the wall. So, here is such a mail box with a fold-away table on both sides. Then everybody has a table, and also their own mailbox. L: Putting it in the center... K: Yes, exactly... putting it entirely in the center. Facilitator: That sounds very drawable, to get a picture of that... (0:16) I: Because clearly it is really hard for number three to reach the bin. |
| 11/K | Mailbox in table over bench length | K: The same, a mail box over the entire length of the three chairs, but then integrated into some kind of a folding table. |
| 12/B | Robot picks up garbage when needed | I: A little robot that picks up everything when you push a button. |
| 13/L | Enlarged railtender | L: An enlarged railtender (coffee cart). |
| 14/Ai | Pounder to reduce volume | M: Or a pounder to... say... reduce the volume. |
| 15/Ai | Pounder operated by pedal if tray is full | M: Yes, or kind of a pedal... that works electrically... the trash bin is too full, people push the pedal, and everything is pounded flat. (0:20) |
| 16/B | Conveyor in aisle | I: A conveyor belt in the middle on which you also throw things. |
| 17/Ai | Higher location for trays | K: The trash bins moved more upward, because nowadays, all bags and stuff are pushed underneath the seats. And that is also more convenient because then you do not have to lift anymore and you can use the upper interior... and then the trash collectors don’t have to bend over anymore... there you go! |
| 18/L | Throwing basket | L: Yes, something like a throwing basket, in which you can throw all trash... I’ll quickly draw it. |
| 19/Bi | Throwing outside through hole in floor | M: Make a hole in the ground and just toss it out... That is how the toilet works too isn’t it? Then you can see the rails too... when you use the toilet? K: Yes, depending on the type of train... the older ones for sure. |
| 20/Ai | Continuous cable-lift with trays | I: A cable-lift with a kind of buckets in which you... they just pass by and you can just put it in there. L: So that they are emptied at the end of the wagon in a big container or something? I: Yes. |</p>
<table>
<thead>
<tr>
<th>20A</th>
<th>Continuous cable-lift with trays</th>
<th>I: A cable-lift with a kind of buckets in which you ... they just pass by and you can just put it in there.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>L: So that they are emptied at the end of the wagon in a big container or something?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I: Yes.</td>
</tr>
<tr>
<td>21K</td>
<td>Tracks-cleaning train</td>
<td>K: Kind of a trash-collecting train that rides behind ... you know, going de-da-da de-lop.</td>
</tr>
<tr>
<td>22M</td>
<td>Conveyor with trays below</td>
<td>M: Or kind of a chain with trash bins that simply rotates.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L: Yes, I had that one too.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M: Oh.</td>
</tr>
<tr>
<td></td>
<td>Facilitator: What did you say, Marc, with trash bins?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M: Yes, something like that ... underneath.</td>
<td></td>
</tr>
<tr>
<td>23A</td>
<td>Chute to garbage wagon</td>
<td>L: You can also make holes, where the trash bins are located now ... and then a trash chute along the outside. (0:24)... and in the back there is a wagon in which the trash is collected for three months.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>L: What I just had is a trash hole where normally is the trash bin and then along the outside a trash chute which transfers the trash to a separate wagon (0:26)</td>
<td></td>
</tr>
<tr>
<td>24K</td>
<td>Big trays on platform, none in train</td>
<td>K: Or big trash bins on the platforms ... no trash bins in the train anymore ... I mean, in the theater you also do not throw it on the ground ... or in the bus.</td>
</tr>
<tr>
<td>25M</td>
<td>Suction</td>
<td>M: Or with suction ... if you then have a little hatch and a can and then you open the hatch and then swoosh! And that can is then sucked towards somewhere.</td>
</tr>
<tr>
<td>26A</td>
<td>Vacuum</td>
<td>I: Vacuum.</td>
</tr>
<tr>
<td>27A</td>
<td>Vacuum makes trash flat</td>
<td>I: And then it is heh heh flat at the same time.</td>
</tr>
<tr>
<td>28K</td>
<td>Big bins in doorway</td>
<td>K: Big trash bins in the waiting rooms, or what is the name of those things?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L: Balconies.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K: Balconies or in-between compartments ... balconies?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L: Yes, balconies.</td>
</tr>
<tr>
<td></td>
<td>K: So that you know that you can walk there if you really need to throw something away immediately.</td>
<td></td>
</tr>
<tr>
<td>29M</td>
<td>Passengers hand garbage over towards trays</td>
<td>M: Have people hand the garbage over ... here I have a picture of that.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K: In Holland?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M: So that people finish the apple and then core and then, catch it. John!</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K: Stimulates social contact in the train.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M: Yes, indeed, to have to make social contact while ...</td>
</tr>
</tbody>
</table>

**study one**
30 | Plastic bags from armrests  
I: Plastic bags on the armrests like in the buses for school field trips. (0:27)

31 | Throwing everything on ground  
L: You can also make an antisocial mess and just throw everything on the ground.
K: That is what they do in Indonesia. That is super cool... you get into a clean train and then you sit in it for four hours... and then you see people, they walk barefooted or in flip-flops anyway, and then they throw everything on the ground! And these people eat!
Facilitator: So just throwing everything on the ground.
L: Yes.
K: That is really normal.

32 | Dogs  
M: There need to be dogs walking around.

33 | Rats eat everything  
I: Or simply lots of rats... they simply eat everything.
M: Yes, throw rats inside.

34 | Grate in floor  
L: You can also make a stable grate in a train, just like in a cow stable, the more liquid-like trash of the cows falls through... You might do it with bigger... (unintelligible).
I: Grate... yes... grate in floor.
Facilitator: Grates through which the trash falls or something?
I: Yes.
L: The smaller things in any case. (0:28)

35 | (grate in floor) and one big hole for bigger trash  
I: Yes, and next to the seats there is one big hole in which you can throw the larger trash or something.
L: And through which your bag falls or something.

36 | Garbage floats to central place on air cushion  
I: You can also pressurize the floor so that if you throw trash on it, it floats in the air and then a pressure towards the trash container or something.

37 | Sliding floor towards corners  
L: You can also have a slanted floor so that everything slides to the sides. Then it just needs to be swept.

38 | Track cleaning wagon in back of train  
K: I have something about the suction train... so that the last part of the train is the suction train.
Facilitator: So, just a suction wagon?
K: Yes, suction wagon.

39 | (Track cleaning wagon) with suction arm  
I: And which then extends its suction arm through the wagon window.
Table 4.3: Idea fragments in the protocol of meeting C, brainstorming with added sketches. (Translated from Dutch)

<table>
<thead>
<tr>
<th>Line</th>
<th>Fragment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 A</td>
<td>Squid on top of train puts arms through windows</td>
<td>I: Well, of course you can also put an octopus on top of the carriage who sticks his arms through the windows in which you can put it and then it sucks as you said... (0:30)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K: You will have to be careful...</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L: Then you need to duck. (laugh)</td>
</tr>
<tr>
<td>41 A</td>
<td>Cleaning with water</td>
<td>M: Something with water, something with water should happen. I think. So that you hear the water flowing in the pipes that you know that it is being cleaned.</td>
</tr>
<tr>
<td>42 A</td>
<td>Flushing bin like toilet</td>
<td>L: Yes, like flushing a toilet... So that you flush your trash bin.</td>
</tr>
<tr>
<td>43 A</td>
<td>Showerhead</td>
<td>M: Some kind of a showerhead or something.</td>
</tr>
<tr>
<td>44 A</td>
<td>Flush it full</td>
<td>K: Some kind of a flushing system, so that if it is full you press a button and then at once it plff... (0:31)</td>
</tr>
<tr>
<td>45 A</td>
<td>Old-fashioned toilet flushing system</td>
<td>L: Or simply such a thing, old-fashioned flushing system.</td>
</tr>
<tr>
<td>46 A</td>
<td>Cart for emptying bins, bottom of bin open automatically</td>
<td>I: For emptying I have a tray that rides under and that you can then tip the bottom, then they don't have to bend over themselves... so as soon as the tray rides under the bin, the bin gets a signal that releases the bottom. (Idea sketch)</td>
</tr>
<tr>
<td>47 A</td>
<td>Flushing and compressing, like garbage truck</td>
<td>K: That also is more like flushing, flushing with compressing as with a garbage truck. (Idea sketch)</td>
</tr>
<tr>
<td>48 A</td>
<td>Spinning ashtray</td>
<td>I: Or like this sort of thing in which you can put out cigarettes, so that you push a button and that it then spins and that it then goes down. (Idea sketch)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M: Oh, yes</td>
</tr>
<tr>
<td>49 A</td>
<td>Water flowing in trash bins</td>
<td>M: Look, here I sketched two waste bins, which leads to a reservoir. (Idea sketch)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K: With water.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M: With water, whatever... This is the reservoir and the idea is that the cleaning person does not really have to clean the bins, instead he stands at the platform and empties the units, empty them each time. Facilitator: So, if I see it correctly that is some kind of a trash bin toilet?</td>
</tr>
</tbody>
</table>

The labels of the fragments, consisting of brief idea descriptions, are put into a matrix display. Their linking with earlier ideas is determined by scoring the previous ideas that appear to be interlinked with the present idea. For each resultant idea, starting with the second idea in the meeting, the backlinks -the links that the idea at hand has with each of the previously generated ideas- are determined, following the procedure described in section 3.5. Figure 4.2 shows the resulting link matrix of meeting C:
4.3.2 Inter-rater agreement

Inter-rater agreement was assessed by determining Cohen's Kappas (see section 3.5). Three judges took part, the researcher and two independent raters. The independent raters were provided with the protocol and a transcription of the flipcharts from the brainstorming section. Table 4.4 shows the instructions for rating links that were provided:

- Determine, for each box in the matrix (representing a potential link between ideas), whether the earlier idea (represented by the row) has contributed to the later idea (represented by the column).

- First carefully study the videotape of the meeting. Then, go through the videotape again small steps at a time, while marking links in the link matrix.

- Work from the bottom upward within each column, starting with idea 2. After finishing the linking in a column, proceed to the next column on the right.

- A link is a direct connection between the earlier idea and the later idea.

- The following indicators, among other things, can help determine whether a link is present or not: (A) Designers relating to earlier ideas when they verbalize their ideas; (B) Similarities in associations; (C) Resemblance in aspects of idea sketches (when applicable) (D) Looking actions; (E) Gestures.

| Table 4.4: Instructions for filling out link matrices |
The independent raters also received verbal instructions, and a sample link matrix was filled out and discussed before filling out the link matrix of meeting C.

The Kappa value for the agreement between rater 1 and the researcher was $K = 0.61$; the Kappa value for rater 2 and the researcher was $K = 0.51$; and the Kappa value for rater 1 and rater 2 was $K = 0.51$. According to Fleiss (1981), these values signify a fair to good agreement beyond chance. It is to be expected that developing structural guidelines for the linking procedure can further enhance the reliability of the method.

**Discussion of results**

**Results**

The researcher constructed the link matrices for the three experimental meetings and the control group meeting. The link matrices for the meetings are presented below, in figures 4.3-4.6. The figures have the same scale. Differences in the sizes of the link matrices are due to the differences in the number of ideas that were generated in the meetings.

![Figure 4.3: Link matrix of meeting A: Graphic facilitator](image)

![Figure 4.4: Link matrix of meeting B: Visual brainstorming](image)
Figure 4.5: Link matrix of meeting C:
Brainstorming with added sketches
(identical to fig. 4.2)

Figure 4.6: Link matrix of meeting D:
Regular brainstorming
When generally inspecting the link matrices, the very small link matrix of meeting B is most clearly noticeable. In this meeting a very low number of ideas is generated. It is also interesting to notice, that in meeting C, most of the links are located along the diagonal, whereas in meetings A and D, the links are more scattered throughout the link matrix’s surface area. This means that, during brainstorming with added sketches, more immediate associations based on the most recently mentioned ideas take place, and that relatively little use is made of the earlier ideas generated.

For each of the meetings, the relative link indicators are calculated. The results are presented in table 4.5.

<table>
<thead>
<tr>
<th>Meeting A: Graphic facilitator</th>
<th>Meeting B: Visual brainstorming</th>
<th>Meeting C: Brainstorming with added sketches</th>
<th>Control group meeting D: Regular brainstorming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of ideas</td>
<td>33</td>
<td>17</td>
<td>50</td>
</tr>
<tr>
<td>Number of links</td>
<td>26</td>
<td>14</td>
<td>50</td>
</tr>
<tr>
<td>Number of self links</td>
<td>6</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Link Density</td>
<td>0.79</td>
<td>0.82</td>
<td>1.00</td>
</tr>
<tr>
<td>Self-Link Index</td>
<td>0.23</td>
<td>0.36</td>
<td>0.20</td>
</tr>
<tr>
<td>Link Type Index:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S (Supplementary)</td>
<td>0.19</td>
<td>0.29</td>
<td>0.14</td>
</tr>
<tr>
<td>M (Modification)</td>
<td>0.35</td>
<td>0.50</td>
<td>0.30</td>
</tr>
<tr>
<td>T (Tangential)</td>
<td>0.46</td>
<td>0.21</td>
<td>0.56</td>
</tr>
</tbody>
</table>

Below, the results of each graphic technique are related to the results of the regular brainstorming technique, which is used as control condition. We also include remarks made by the designers during the group discussion after the meeting, regarding the functioning of the graphic technique applied. As in the group discussion all the meeting steps were reviewed, a relatively short time was used for evaluating the graphic adaptations to brainstorming in the first idea generation step. The following procedure was followed for identifying interesting issues in the group discussion. First, the videotapes of the group discussions were transcribed and fragments containing single topics were identified. Each fragment was then provided with a label describing the subject matter of the fragment. Table 4.6 provides an overview of all the labels in the group discussions that dealt with the functioning of the graphic variation to brainstorming applied.
Table 4.6: Overview of fragments in the group discussion. Fragment labels in italic script are not used in the discussion of the results of the various techniques, because they appear less relevant for assessing the functioning of the techniques.

<table>
<thead>
<tr>
<th>Meeting A</th>
<th>Meeting B</th>
<th>Meeting C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphic facilitator</td>
<td>Visual brainstorming</td>
<td>Brainstorming with added pictures</td>
</tr>
<tr>
<td>- No need for hiring a special graphic facilitator, everybody could do this job</td>
<td>- Sketching ideas is a fun challenge</td>
<td>- Drawing is slower than talking...lagging behind</td>
</tr>
<tr>
<td>- Graphic facilitation is tough work</td>
<td>- Sharing ideas verbally before drawing them, may reduce double work and it helps to receive ideas from others.</td>
<td>- You miss something when you are sketching</td>
</tr>
<tr>
<td>- Graphic facilitator is required to make interpretations of ideas.</td>
<td>- Very focused on own drawings, but hearing ideas from others is helpful</td>
<td>- Drawing makes ideas concrete, even if that is not desired.</td>
</tr>
<tr>
<td>- Graphic Facilitation takes longer than writing...blocks the flow of ideas.</td>
<td>- Idea flow dries up quickly</td>
<td>- It is easy to retrieve ideas during converging, you can quickly scan ideas</td>
</tr>
<tr>
<td>- Having to wait for the graphic facilitator to be ready to air ideas.</td>
<td>- Fixated on one picture, therefore limiting the problem space</td>
<td></td>
</tr>
<tr>
<td>- Makes suspending judgment difficult...constantly looking if the ideas had not come up before</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Suggestion: sentential note-taking, enriched by sketches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Pictures have creative potential</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Paradox: pictures inspire creative thinking and block the flow of ideas</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As this study is purely exploratory in nature, it is useful to include the experiences of the participants when analyzing the functioning of the various graphic variations. The remarks made by the designers provide a rudimentary kind of triangulation that can help strengthen the inferences made through analyzing the link matrices.

4.4.2 Graphic facilitator (meeting A)
The graphic facilitator technique shares some of the basic characteristics of the regular brainstorming technique. For both techniques, the linking in the link matrix appears to be scattered throughout the matrix. The link type indices of the two
meetings are similar, with comparable proportions of supplementary, modification, and tangential linking. The self-link indices of the two techniques are both according to what could be expected in a 'full' group process (see section 3.5), which for a group of four members is expected to be around or below the value of 0.25. However, both the number of ideas generated and the link density are substantially lower for the graphic facilitator, compared to regular brainstorming.

In the group discussion two issues came up, related to the graphic facilitator requiring relatively long to make sketches. The first issue dealt with the participants feeling that their flow of ideas was blocked, because they had to wait until the graphic facilitator finished a sketch of an idea. Designer F mentioned: "I felt it very clearly in the beginning ... this takes too much time, writing is faster." And designer T made similar remarks: "I felt it a bit of a struggle...you could not directly shed your ideas. And I also think that things were said that did not end up being drawn... I was really waiting until [the graphic facilitator] finished drawing and only then could one say new things."

The second issue also dealt with the fact that it takes longer to make a notation of an idea by means of sketching, in compared to writing. The participants found that, when someone proposed an idea, instead of directly writing down the idea, they would first search the earlier ideas, to check if the idea had come up before. Designer E suggested that this blocked the idea generation process, by introducing some kind of idea screening in the divergent phase: "I thought it was a nuisance that I was terribly tempted to not let whatever was there [on the flipchart] come up again".

A different topic that came up in the group discussion was the need for the graphic facilitator to interpret ideas, in order to be able to represent them by means of sketches. The designers saw this interpretation both negatively and positively. For instance, designer F said, "...my fingers really started itching ... because I did not intend it [the idea] that way at all." Designer E thought the interpretations of the graphic facilitator were conducive to creativity, because they open up new directions: "I did like the fact that if you go to your own idea, I mean this idea of mine turns into Mr. Clean (see figure 4.7) ... I mean, that is an entirely different leap, because you have a visual association yourself, you translate that, and it is translated back into a picture again... Then you get other things."

Designer G made a concluding remark that may be fitting: "It is a paradox. ... that while diverging, in which a picture is really more inspiring, you use a technique that is much slower and because of that, it hampers the diverging."

Using a graphic facilitator does not appear to help the process. If anything, it obstructs the process. The number of ideas generated is much lower than for brainstorming. The link density is also lower, which means that this technique fails to comply to both the 'strive for quantity' and the 'make connections' guideline.
In the discussion, the graphic facilitator—who, like the participants, was an advanced product design student, but who was a talented sketcher as well—suggested removing the blocking of the process due to the waiting time, while maintaining the graphic representations. He proposed writing ideas down as in regular brainstorming, but to also have someone sketch some of the interesting ideas. That way, the flow of ideas would not be hampered, while visual stimulation through idea sketches would still be provided. The graphic facilitator mentioned: "I know that drawings can work, someone for instance started to generate ideas which involved the feelers of a snail (see figure 4.8) ... And I do not know that if it [the notation on the flipchart] would just say ‘snail’ that you would also get to that... So maybe it would work to have someone write down ideas like a regular facilitator and that to have someone else drawing pictures...". This remark lead to the hybrid technique applied in meeting C, which involved both written language and sketching.

4.4.3 Visual brainstorming (meeting B)

During the visual brainstorming technique, in which the participants were asked to sketch their ideas before sharing them, the number of ideas generated was extremely low, only 17. The link density is relatively low as well, comparable to the link density found in the graphic facilitator technique. Also, the self-link index is particularly high, which indicates that the idea generation process has a more individual orientation. Combined, this means that for the visual brainstorming technique also, the ‘strive for quantity’ and the ‘making connections’ guidelines are less well met, compared to the regular brainstorming meeting. In addition to this, the tangential link type index is especially low and the supplementary link type index is especially high, which suggests that the idea generation process is more based on small improvements and direct associations, rather than making wild leaps to explore novel directions.

In the group discussion three issues surfaced. The first one dealt with the individual focus of the technique. For instance, designer D mentions: "Yes, you are very focused on your own drawing... It has been a much more individually oriented meeting, compared to the meetings that we had during CPO [the name of the course in creative problem solving]". The second issue related to the designers running out of ideas prematurely. Designer D, again, mentions: "Your flow of ideas dries out quicker...when you are allowed to shout out your ideas then you have ten options, and if you have to draw then you have three and then you do not know anymore." The third issue related to the fact that the designers were not able to make novel connections, or wild leaps. Designer A mentions, "I felt that we were very fixated on the picture in the left upper corner [picture provided on one of the flipcharts, consisting of a sketch in perspective of the lay-out of the seats in the train]...Only after someone suggested that it [the litter] could also be picked up by someone who..."
walks by (see figure 4.9), I all of a sudden thought, well, there is also the conductor..."

The designers had difficulties in breaking loose from the notion that the litter disposal system should be an element of the seat set-up that could be interchanged with the existing trash bins. Even though some of the ideas within these boundaries are quite inventive (for instance, see figure 4.10), the presupposition of accepting the train's interior unnecessarily constrained the search.

The participants feeling drained after few ideas, combined with both the low link density and the high level of supplementary-type linking in this early idea generation step, suggest that in this meeting, what Goel (1995) calls 'early crystallization' took place (see section 2.2). The designers had problems breaking away from the solution direction of the early ideas generated. Finally, the focus of the participants on their own sketching appeared to disrupt the flow in the brainstorming process.

**Brainstorming with added sketches (meeting C)**

As both visual techniques appeared to be sub-optimal, we tried out a technique that was meant to allow for a continuous flow of ideas, as in regular brainstorming, but that also included sketches. The underlying assumption was that including sketches could improve the accessibility of the earlier ideas. In the brainstorming with added sketches technique, the participants verbalized their ideas. The facilitator wrote these ideas on a flip chart, as in regular brainstorming. However, the participants were also invited to make sketches of their ideas, if they felt that this would add to their ideas. These sketches were pasted next to the written notation of the ideas on the flip chart.

For the brainstorming with added sketches technique, the number of ideas generated and the link density are comparable to the regular brainstorming technique. The Self-Link Index is especially low, which signifies that the participants make many connections with each other's ideas. The tangential link type index is especially high in meeting C, which means that there is a high level of 'wild leap' type connections made.

The structure of the links in the link matrix shows that most of the links are made close to the diagonal of the matrix, which means that mostly immediate connections are being made. This may be due to the fact that during brainstorming with added sketches, the sketched ideas are brought to the attention of the designers twice. Once by means of a verbal expression and the facilitator writing down the idea, and then again by the designer giving the sketch to the facilitator, which is often accompanied by some further verbal explanation of the idea.

For instance, designer K mentions an idea of a train that rides behind the passenger train and sucks up the trash from the rails (in order to allow the passengers to just throw their trash out of the windows). He mentions the idea and
then starts sketching. While K is sketching three other ideas are mentioned. Then he presents the sketch of his idea: "look, this is the suction train" (see figure 4.11).

This probably directs the focus of the meeting towards the last few ideas mentioned, instead of the group members exploring the full range of earlier ideas as a source for making new connections.

In the group discussion, most remarks regarding this technique were related to the individual focus of sketching. The designers felt that they stepped out of the group process to make a sketch, and when they re-entered the group process it had proceeded, so that the sketched idea sort of lagged behind. Designer M mentioned: "I noticed that sketching is always slower than talking. When you are talking and then you are sketching and then you are further than..." Designer I concurs: "Yes, that is difficult too, when you are still working on for instance [idea] number two and then we are all of a sudden five ideas ahead". Designer L gives special attention to the fact that when sketching, the designers disconnect from the group process: "Yes, you just miss something when you are sketching". Designer L also makes a remark about sketching making ideas too concrete, and he provides a suggestion: "You can also after each step that you have made with words, have it so that then everybody individually takes the useful things and starts drawing them ... Because I think it is a shame that if you draw something it is immediately quite concrete."

The link indicators for the technique appear favorable, even though the designers had some critical remarks about this technique in the group discussion. However, the technique was primarily intended to enhance building on earlier ideas by providing better access to these earlier ideas. The opposite occurred; most of the linking took place with the last few ideas mentioned.

4.5 Conclusion

In the experimental meetings we explored various ways of including sketching in the brainstorming technique. Taking away the written words used for recording ideas in regular brainstorming and replacing them with sketches, either made by the facilitator, or by the participants, appears to interrupt the brainstorming process. Adding sketching to the brainstorming technique, while maintaining the writing down of ideas by the facilitator does not appear to interrupt the process, but it does substantially alter the linking process.

With these results, we can start to answer the additional research question: Are the processes of brainstorming and idea sketching compatible? To recall, in order to be compatible, sketching needs to enhance, or at least not deteriorate the functioning of the brainstorming technique. Whether or not this is the case can be examined by assessing the extent to which the graphic variations to brainstorming applied follow the four basic guidelines for divergent thinking. Below, the functioning of the graphic variations is examined for each of the four guidelines.
Striving for quantity: Compared to regular brainstorming, replacing written notations with sketches reduced the number of ideas generated. Allowing for sketching in addition to written recording of ideas did not reduce the number of ideas generated.

Seeking combinations: In the fully graphic techniques, ideas have fewer connections with earlier ideas. In addition to this, the visual brainstorming technique results in a process that is more individually oriented. The brainstorming with added sketches technique, that included both means of expressing ideas had a similar level of linking compared to the brainstorming technique. However, the structure of the linking is different compared to the regular brainstorming. The process of making combinations is more based on making immediate connections, whereas during regular brainstorming more linking takes place with the earlier ideas generated.

Freewheeling: As explained earlier, the freewheeling principle asks for tangential-type links. Visual brainstorming, in which the participants sketched their own ideas, appears to lean heavily on small improvement type connections between ideas. Brainstorming with added sketches has an especially high level of tangential type links, which signifies a high level of novel connections made.

Deferring judgment: Analyzing the linking of ideas does not lead to insights regarding the way in which the graphic variations meet or obstruct the deferred judgment guideline. However, remarks made during the group discussions suggest that the designers experienced critical thinking while engaged in visual brainstorming and the graphic facilitator technique. Sketching appears to require a certain level of commitment to an idea. No matter how quick the sketch, making a graphic representation on paper takes more time and contemplation than simply verbalizing the idea, or even writing it down. This may evoke some kind of a first idea screening, thus introducing judgment into the divergent phase.

This research project was initiated with the notion that designers use both brainstorming and sketching to stimulate their creativity, and that combining the two may provide an even better tool for stimulating creativity. Contrary to this assumption, the results of this exploratory experiment suggest that idea sketching is not compatible with the brainstorming process. Replacing the written recording by sketching appears to deteriorate the idea generation process, with regard to the ways in which the guidelines for divergent thinking are met.

Because of the findings in this experiment the aims of the research need to be redirected slightly, from identifying the benefits of including sketching in brainstorming, and further development of idea generation techniques that include sketching, towards gaining an understanding about the characteristics of the group's idea generation process when sketching is involved. The main research question then becomes: What are the differences in the structure of idea generation...
processes, when sketching or written language is used as a working medium? This is the second main research question of this thesis. The first main research question, concerning the ways in which sketching can be included in idea generation meetings in product design, and how that affects the idea generation process, can be dealt with subsequently.

Notes:

1 This chapter is based on an earlier article in Design Studies (Van der Lugt, 2000)
Comparing a graphic and a 5 sentential technique for generating ideas

Introduction 5.1

The results from the first, exploratory, study (Chapter 4) indicate that the processes of idea sketching and brainstorming cannot be superimposed. Apparently, including sketching in idea generation meetings structurally changes the idea generation process. This lead to a shift in direction of the research project towards gaining further understanding regarding the ways in which the idea generation processes are different when sketching rather than writing is used as a working medium. This leads to the main objective of this empirical study, which is to investigate the differences in idea generation processes that occur when sketching or writing is used as a working medium.

Techniques that use sketching as a medium for expressing ideas are referred to as graphic idea generation techniques and techniques that use writing for expressing ideas are referred to as sentential idea generation techniques. The results from the first study suggest a distinction in the structure of the idea generation processes. In this chapter the characteristics of the graphic and of the sentential idea generation processes are further investigated by means of an empirical study. In this study the processes of idea generation meetings under sketching and under writing conditions are compared. The research design is set up to enable a paired comparison of the linking processes of the individual designers for both the graphic and the sentential condition. In section 5.2, the research design is described in detail. Section 5.3 describes the method of analysis used for constructing the link matrices. The principal research question in this chapter is:

What are the differences in the structure of the idea generation processes, when sketching or written language is used as a working medium?

This question will be answered primarily by investigating the general link indices, as described in Chapter 3. However, an additional indicator may be useful. In Chapter 2, we identified three different functions of sketching in design theory. To recap: First, sketching may support creativity in individual design activity by evoking a quick reflective cycle. Secondly, sketching may support creativity in group design activity by allowing for re-interpretation of each other's ideas. Finally, sketching may support building on earlier ideas by facilitating the retrieval of these earlier ideas. These functions are related to different aspects of sketching as a working medium. Some are related to the designers' individual idea generation
processes and other aspects are related to interpersonal activity. Some aspects are related to immediate idea generation processes and other aspects are related to longer-term idea generation processes, which involve making use of the ideas that are not within the current scope of attention. In order to achieve a thorough understanding of the structure of the graphic and sentential idea generation processes, it is necessary to address this differentiation in various aspects of the group's interaction with their working media. In section 5.4, an additional link indicator is developed which determines the link densities for these various aspects of interaction with the working media.

In section 5.5 the results of the study are presented by comparing the sentential condition and the graphic condition for each of the link indicators. The results of this study are summarized in section 5.6 by providing characteristics and examples for the typical sentential idea generation process and the typical graphic idea generation process.

5.2 Experiment design

5.2.1 A paired comparison approach
In the exploratory study, a conventional experimental design was applied; the three experimental meetings were subject to different graphic idea generation techniques, and in a fourth meeting brainstorming was applied as a control condition. The main difficulty with the approach taken in the exploratory study was that each of the idea generation techniques was applied to a different group of designers. These differences in group composition were not taken into account when analyzing the results. The assumption made was that the circumstantial variables, such as the group composition, were less influential than the differences due to the variations in idea generation techniques applied. To strengthen the results, the link indices were related to remarks made in the group discussion. This provided coarse results, which were sufficient for an exploratory study. In the present study, a more refined research design is required.

Based on the experience that we gained in the exploratory experiment, we opted for a paired comparison approach to investigating the differences in process between graphic and sentential idea generation techniques. A paired comparison approach enhances the dependability of the results, while keeping the number of experimental meetings required relatively small. Such a paired comparison approach involves applying both techniques to be compared in each meeting (see figure 5.1).
In a paired comparison approach, differences in results for the experimental treatment are compared for each unit of research. In this study, the units of research are the individual designers in the group meetings, which means that each designer is subject to both the graphic and the sentential technique, and that for each designer the differences in results for both conditions are compared. This way, many of the circumstantial variables are excluded from the comparison. For the current study, this means that both a graphic and a sentential technique were applied in each of the experimental meetings and that the various link indicators were calculated for each designer.

One thing to be wary of when taking a paired comparison approach is the possible order effect. The problem-solving behavior of groups may develop over time. As the meeting progresses, group members acquire knowledge of the problem situation, and they learn about their ways of working together (e.g. Tuckman & Jensen, 1977). The issue of the differences in problem solving behavior through the increased knowledge of the task for the second technique applied can be compensated for by altering the problem-solving task between the first and the second segment of generating ideas in the meeting. The issue of the potential differences in problem-solving behavior due to group development cannot easily be compensated for. However, by allowing the groups to get used to being in a idea generation meeting together, before the actual experimental idea generation segments take place, the groups had the opportunity to pass the initial state of group development. Then, both idea generation segments are more likely to take place within the same state of group development.

To further compensate for order effects, and to be able to inspect the data for order effects, in two of the meetings, first the sentential idea generation technique is applied, followed by the graphic idea generation technique. In the other two meetings, first the graphic idea generation technique is applied, followed by the sentential idea generation technique. This leads to the following basic experimental set-up (see table 5.1):
Table 5.1: Basic experimental set-up

<table>
<thead>
<tr>
<th></th>
<th>Meeting 1</th>
<th>Meeting 2</th>
<th>Meeting 3</th>
<th>Meeting 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>First idea</td>
<td>Sentential</td>
<td>Sentential</td>
<td>Graphic</td>
<td>Graphic</td>
</tr>
<tr>
<td>generation segment</td>
<td>technique</td>
<td>technique</td>
<td>technique</td>
<td>technique</td>
</tr>
<tr>
<td>Second idea</td>
<td>Graphic</td>
<td>Graphic</td>
<td>Sentential</td>
<td>Sentential</td>
</tr>
<tr>
<td>generation segment</td>
<td>technique</td>
<td>technique</td>
<td>technique</td>
<td>technique</td>
</tr>
</tbody>
</table>

Unit of research

Group level

Individual level

In the exploratory study, the design group was the main unit of research. The main analysis consisted of assessing the link indices for each group meeting. In the group level of analysis, interactions within a group are investigated. Interpersonal links and self-links are noted, without taking into account which person is the originator of the source idea in the link, or which is the originator of the resultant idea.

In the individual level of analysis, the individual designers within the groups are the basic research unit, which means that the aspects about the originators of ideas within links are included in the research data. The available information in the link matrices allows for such an increased level of resolution (see figure 5.2).

In fact, the link indices used in the exploratory experiment provide averages of the group member’s linking. For instance, the link density of the group in figure 5.2 is equal to the mean of the individuals’ link densities:

\[
LD_{GROUP} = \text{Average} \left( LD_A + LD_B + LD_C + LD_D \right) \\
= \frac{N_{LINKS,A}}{N_{IDEAS,A}} + \frac{N_{LINKS,B}}{N_{IDEAS,B}} + \frac{N_{LINKS,C}}{N_{IDEAS,C}} + \frac{N_{LINKS,D}}{N_{IDEAS,D}} / 4
\]

The increased quantity of units of research also allows for basic statistical operations to verify the significance of the differences in link indices found between the two techniques. The current study consists of four experimental meetings with five designers each. This means that if we were to study the data on a group level, we would have four pairs of cases to compare, corresponding with the graphic and the sentential technique segments in each meeting. For the individual level there are twenty pairs, corresponding with the sentential and graphic idea generation segments for each designer. For each designer, the link indices are determined. The significance of the differences in means between the two techniques can then be determined by means of a paired-sample t-test (calculations were done in SPSS 10 for Macintosh).
Two representatives of idea generation techniques

There are three -potentially conflicting- requirements that representatives of idea generation techniques need to meet in order to be suitable for this study.

1. The techniques need to predominantly use the working medium that they are representatives of, and they need to make optimal use of the qualities of that working medium.

2. The techniques need to be comparable. They need to share as many characteristics as possible, except for the working medium used, which needs to be distinct. Any differences in the technique applied, besides the differences in working medium obscure the differences in results between sketching and writing in idea generation techniques.

3. The techniques need to be practical. This means that each technique needs to be workable and competent. Representative techniques should ideally be proven in practice.

To illustrate the potential conflict in requirements, consider the following example. In design, idea sketches are often accompanied by annotations. These written remarks are important to the creative design process, for instance, Fish & Scrivener (1990) describe how these annotations are important in the designing cycle which moves back and forth from description and depiction (see section 2.2 for an outline of Fish & Scrivener’s theory on the characteristics of sketches). Such annotations cannot be eliminated without disrupting the idea sketching process. Consequently, the representative of graphic idea generation techniques needs to be strongly based on sketching, without violating the characteristics of the underlying creative process. This means that concessions may need to be made towards the distinctness of the techniques, to allow for the technique to remain practical. In our case this may entail allowing the designers to add written annotations to their sketches.

The basic brainsketching technique is a graphic variation of the brainwriting technique (Geschke et al., 1973). During brainsketching, participants individually sketch ideas on posted flipcharts. After a couple of minutes the group members shift flipcharts and continue to sketch ideas. The idea sketches already present on the flipchart are used as a source of inspiration for new ideas. Usually about five such rounds of idea sketching take place. Brainsketching has already been described in Chapter 1 as one of the graphic techniques found in the creative problem solving literature (see section 1.4). It was also reported that this technique was developed independently by design students, in order to satisfy their need for including sketching in idea generation meetings. This meets the third requirement; by being conceived in practice, this technique shows practical applicability. The predominant

5.2.2
Requirements for selecting representative idea generation techniques

Brainsketching as a representative of graphic idea generation techniques
mode of expression used is sketching, while sentential annotations have a more peripheral function of, for example, clarification (see figure 5.3).

Brainsketching allows the designers to be involved in a group idea generation process while at the same time it allows the designers to generate ideas individually, allowing the designers to engage in what Schön & Wiggins (1992) describe as a reflective conversation with their drawings. This means that brainsketching makes good use of the characteristics of sketching, which meets the first requirement.

The version of brainsketching that was reported in Chapter 1 is entirely nonverbal. Designers sketch ideas in silence and then pass on their sheets of ideas. Building on earlier ideas is stimulated by asking the designers to first browse through the earlier ideas on the sheet of paper, before generating new ideas. The presupposition is that more of a group-oriented process can be achieved by allowing the designers to briefly explain their ideas after each round of idea sketching. This can increase the designers’ understanding of each other’s ideas, which may enhance the amount of building on each other’s ideas taking place. This revision to the brainsketching technique will be referred to as ‘interactive brainsketching’.

To explore whether interactive brainsketching indeed provides a more group-oriented idea generation process, a small pilot study was executed. This study consisted of two fragments of the design group meeting described in section 3.4 (see Van der Lugt, 1999 for a more detailed report of this pilot study). During this meeting, regular and interactive brainsketching were applied for two different sub-focus areas of the problem statement. The link density, the self-link index, and the link type indices were determined for both segments. The results of this pilot study are presented in table 5.2.

<table>
<thead>
<tr>
<th></th>
<th>Regular brainsketching</th>
<th>Interactive brainsketching</th>
</tr>
</thead>
<tbody>
<tr>
<td>Link density</td>
<td>1.00</td>
<td>1.13</td>
</tr>
<tr>
<td>Self link index</td>
<td>0.41</td>
<td>0.27</td>
</tr>
<tr>
<td>Link type indices:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supplementary</td>
<td>0.09</td>
<td>0.23</td>
</tr>
<tr>
<td>Modification</td>
<td>0.49</td>
<td>0.56</td>
</tr>
<tr>
<td>Tangential</td>
<td>0.43</td>
<td>0.21</td>
</tr>
</tbody>
</table>

The results show that the link density is higher for interactive brainsketching (LD regular = 1.00; LD interactive = 1.13), and the self-link index is lower for interactive brainsketching (SLI regular = 0.41; SLI interactive = 0.27). The revision of brainsketching indeed appears to enhance the group process, as the designers make more connections with each other’s ideas.
Also, an issue of concern surfaced. The link type indices show that the tangential link type index is lower for interactive brainsketching ($LTI_T$, regular = 0.43; $LTI_T$, interactive = 0.21) and the supplementary link type index is higher ($LTI_S$, regular = 0.09; $LTI_S$, interactive = 0.23). This suggests that the revision includes fewer wild leaps into new directions, and more incremental development. In section 2.2 we already observed that misinterpretation of each other’s idea could lead to interesting new search directions. Perhaps, the increased level of understanding of each other’s ideas provides less opportunity for such ‘creative’ misinterpretation to take place.

The revision of brainsketching was primarily intended to enhance the building on each other’s ideas. It appears that the revision succeeded in doing so, but perhaps at the cost of a reduced number of wild leaps. As primary importance is given to achieving a full group problem solving process, the revision of brainsketching will be used as a representative of graphic idea generation techniques. If such a lack of tangential linking occurs in the main study, interactive brainsketching needs to be re-evaluated as a representative of graphic idea generation techniques.

Selecting brainsketching as a representative of graphic idea generation techniques suggests choosing brainwriting (Geschka et al., 1973) as a representative of sentential idea generation techniques, as brainsketching is a direct graphic variation of the brainwriting technique. Brainwriting thus meets the comparability requirement. However, brainwriting tends to result in very high numbers of ideas with little variation among the ideas (Gryskiewicz, 1988). Isaksen, Dorval, & Treffinger (1998) organized idea generation techniques along a spectrum of the probable characteristics of solutions, based on Kirton’s (1989) adaptor-innovator theory of problem solving styles. They positioned brainwriting on the far ‘adaptor’ side of the spectrum, mainly based on Gryskiewicz’s findings. Isaksen et al suggest using brainwriting when a very high number of ideas within a few themes are required. The main asset of brainwriting, according to Isaksen et al, is that it provides for anonymity, and therefore can be used when group members are reluctant to share their ideas. Because of the extremely adaptive orientation, brainwriting can not be seen as exemplary for the class of sentential associative idea generation techniques. As our objective is to gain an understanding of the differences in process characteristics of graphic and sentential idea generation techniques, it is more suitable to slightly compromise on comparability, because it is more useful to investigate techniques that are typical for their mode of representation.

The basic brainstorming technique (Osborn, 1953) is the epitome of associative sentential idea generation techniques and as such it meets the requirement of being representative. The technique also meets the requirement of being practical by having a 50-year history of proof in practice and research (see Stein, 1975, for an
overview of the first 25 years of brainstorming research and Isaksen, 2000, for an updated bibliography).

Brainstorming consists of generating ideas in a facilitated group situation while observing the four guidelines for divergent thinking: defer judgment, strive for quantity, freewheel, and build on other ideas (see section 1.2). Most other associative idea generation techniques are modifications of this technique, developed to overcome a certain limitation of the original technique. For example, the previously mentioned brainwriting technique is a non-verbal variation on brainstorming, developed by the German Battelle Institute (1972), with the intention of removing potential negative group dynamics from the idea generation process.

During brainsketching, participants sketch their own ideas, while in brainstorming the facilitator functions as the note-taker. By having the participants, rather than the facilitator, record ideas while brainstorming, the comparability of the sentential and the graphic technique can be enhanced. The brainstorming with post-its technique (Isaksen et al, 1994) is a slight variation on the brainstorming technique, developed to increase the speed of recording ideas. During brainstorming with post-its, group members generate ideas by writing them down on large post-its in a clear and legible manner. After having written down an idea, a group member explains the idea to the group and then hands the post-it with the idea to the facilitator. The facilitator then pastes the idea onto a flipchart. According to Isaksen et al (1998), brainstorming with post-its is likely to result in the same types of options as would be generated by regular brainstorming. Brainstorming with post-its enhances the way in which the comparability requirement is met without violating the requirements of being representative and practical.

5.2.3 The idea generation task

The assignment that needs to be developed for this experiment needs to comply with two sets of task requirements. Dorst (1997) provides a set of qualifying factors for experimental design tasks. A design task need to be: "Challenging, realistic, appropriate for the subjects, not too large, feasible in the time available and within the sphere of knowledge of the researchers" (p.92). The other set of task requirements is related to the characteristics required of problems in order to be suitable for creative problem solving. For idea generation meetings that focus on the ‘generating ideas’ component of the creative problem solving model this means that the task needs to express an explicit need for many, varied or unusual ideas. Furthermore there needs to be a clear understanding of the problem to be solved (Isaksen, Dorval and Treffinger, 1994).

The following design assignment was developed with these requirements in mind: 'How can it be made fun for children to travel by car?' The designers were asked to generate ideas for products for a particular multi-functional family car with a
flexible interior, called the 'Vista', produced by car manufacturer 'Voiture' (company name and car type are fictional). This task was based on an actual assignment for a Dutch product design agency.

In order to achieve an understanding about the solution space and to test the design task, the design task was tried out as a group student assignment in a fourth year course on design methods. Solutions that appeared regularly consisted of playing tables in front of the child seat (see figure 5.4 for an example), toy dashboards (figure 5.5), stuffed animals with a simple electronic feature (figure 5.6) and traveling oriented video games (figure 5.7).

The course teachers and the researchers observed that a relatively large number of the design solutions provided by the students seemed rather conservative. Little specific use was made of the flexibility of the car interior. Also, electronic devices tended to be limited to a rectangular display with some story or game inside. Such solutions avoided the integration of form and function, which is a characteristic of conceptual product design (Christiaans, 1992). Product ideas that rely heavily on electronics should therefore be avoided in the actual experiment.

Some specific suggestions were added to the design brief to direct the designers. To stimulate the designers to move beyond 'obvious' solutions, the design brief explicitly mentions the need for fresh and unusual ideas. To avoid the designers ending up generating ideas for general toys, rather than specific solutions for the Vista, the design brief mentions that explicit use of the possibilities of the flexible interior is desirable. Finally, the participants were discouraged to using electronics for the reasons mentioned above. This lead to a short design brief, which was given to the participating designers a week before the experimental meetings (see figure 5.8. The design assignment is translated from Dutch.)

In order to provide enough of an understanding of the problem, four A3-size cards with key information regarding the assignment were provided. These cards covered the following areas: (1) Principal characteristics of the Vista car, including the possibilities of the flexible interior. (2) Ergonomics; covering basic dimensions and sitting positions of three- and nine-year-olds in the Vista. (3) Playing behavior of three- and nine-year-old children, and parents' preferences regarding toys. And, (4) Examples of toys for three- and nine-year-olds, which consisted of pictures and short descriptions of toys that were nominated for the 1999 Dutch ‘toy of the year’ awards. Before each meeting, the researchers briefly explained the design task and its context with use of these cards. During the meetings the information cards were placed on the table so that they were available for the designers to refer back to.
Design assignment

Car manufacturer Voiture carries in her portfolio the multi-functional family car Vista. Because of the flexibility of the back interior, this car is very well suited to a variety of functions.

Voiture would like to strengthen the Vista’s position as a family car. The car manufacturer is aware that children tend to get bored quickly while in the car. Voiture has the intention of offering an accessory kit, which allows for children to enjoy spending time in the car.

Earlier product proposals were rejected by Voiture, because they were not sufficiently innovative and they did not make sufficient use of the specific qualities of the Vista. Voiture is not inclined to include extensive electronics into the kit, because they may make the kit too expensive and it detracts from the car’s functional image.

Voiture asks you to generate a large number of fresh and unusual product ideas for two age categories; three- and nine-year-olds. The problem statement to be used is: ‘How can it be made fun for children to travel by car?’

Figure 5.8: The design assignment

5.2.4 Group composition

Each group consisted of five designers. These were fourth or fifth year product design students who were, at the time, involved in the final stages of a course in facilitating creative problem solving meetings. This ensured that the participants were sufficiently familiar with participating in idea generation meetings, and with each other.

To assess the participants’ style of problem solving, the designers filled out the Kirton Adaption-Innovation Inventory, more commonly known as the KAI (Kirton, 1989), one week before the experimental meetings took place. The KAI is a short paper and pencil instrument, which places the subject on a spectrum of problem solving style. A low score on the KAI signifies an adaptive problem solving style, which indicates a style of problem solving that is predominantly based on gradual improvement. A high KAI score signifies an innovative problem solving style, which indicates a style of problem solving that is predominantly based on seeking radical
changes. The designers also filled out a small questionnaire that covered personal information and self-assessment of sketching ability. The self-assessment of sketching consisted of three statements. The designers marked on a five-point scale how well the statement applied to them. The questions were: 1) I often use sketching to make things clear; 2) I am a good sketcher, and; 3) I am a fast sketcher. The mean of the three items provided a crude self-perceived sketching ability score.

Based on this information, the four groups were matched in terms of the designers' problem solving style, sketching skills, experience with the design task, and gender. Three groups consisted of three male and two female designers and one group consisted of three female and two male designers. In each group, one participant had a relatively high KAI-score (in comparison to the design group's mean score), signifying a relatively innovative style of problem solving, and one participant had a relatively low KAI-score, signifying a relatively adaptive style of problem solving. The groups were also matched in terms of self-perceived sketching skills. In each group, there was at least one designer with high self-perceived sketching skills, and at least one with low self-perceived sketching skills. Finally, the groups were matched in terms of the participants' familiarity with the design task. Some of the designers had participated in the design methodology course mentioned earlier, in which the design assignment had been tried out. As the nature of the design exercise differed substantially from the experimental meetings, these participants were allowed to participate in the experiment. This had the added benefit of simulating the role of expert in the idea generation groups. The expert role is commonly present in creative problem solving meetings in practice. Often there are participants present in the meetings who are very familiar with the subject. These experts are a source of knowledge to the group, but they also need to overcome their limited view on the problem situation. Including participants who have previous experience with a related design assignment introduces a similar dynamic in the experimental meetings (Buijs & Valkenburg, 2000).

Meeting plan 5.2.5

Each meeting took approximately 105 minutes. The process plan for each meeting included a warming-up activity, a round of exploring the problem, two rounds of generating ideas, and a short group discussion. The facilitators received a detailed script of the meetings and were briefed in advance. Table 5.3 shows the main steps in the experimental meetings:
<table>
<thead>
<tr>
<th>Step</th>
<th>Time</th>
<th>Activity</th>
<th>CPS phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0:00-10:00</td>
<td>Introduction and warm-up activity</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>10:00-20:00</td>
<td>Briefing on problem</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>20:00-35:00</td>
<td>Exploring the problem by generating options for</td>
<td>Finding the Problem, diverging</td>
</tr>
<tr>
<td></td>
<td></td>
<td>the following questions: &quot;What did you play when</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>you were a kid?&quot; and, &quot;Why was this fun?&quot;</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>35:00-40:00</td>
<td>Selecting most inspiring options generated</td>
<td>Finding the Problem, converging</td>
</tr>
<tr>
<td>5</td>
<td>40:00-55:00</td>
<td>Generating ideas through brainstorming with post-its (meetings 1 and 2)</td>
<td>Generating Ideas, diverging</td>
</tr>
<tr>
<td></td>
<td></td>
<td>or brainsketching (meetings 3 and 4)</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>60:00-65:00</td>
<td>Selecting Ideas</td>
<td>Generating Ideas, converging</td>
</tr>
<tr>
<td>7</td>
<td>65:00-70:00</td>
<td>Break</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>70:00-90:00</td>
<td>Generating ideas through brainsketching</td>
<td>Generating Ideas, diverging</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(meeting 1 and 2) or brainstorming with post-its (meeting 3 and 4)</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>90:00-95:00</td>
<td>Selecting Ideas</td>
<td>Generating Ideas, converging</td>
</tr>
<tr>
<td>10</td>
<td>95:00-105:00</td>
<td>Debriefing through short group discussion</td>
<td></td>
</tr>
</tbody>
</table>

The two divergent idea generation steps (steps 5 and 8) provided the primary data for analysis. The first three steps were mainly intended to simulate a idea generation meeting by briefing the participants on key issues and by having the designers briefly explore the problem situation in order to become more familiar with the task, and with each other.

In each meeting, brainstorming was applied in one of the idea generation steps and brainsketching was applied in the other. The order of application of these techniques was varied; in two of the meetings brainstorming with post-its was applied first, followed by brainsketching, and in the other two meetings, brainsketching was applied first, followed by brainstorming with post-its. Each idea generation step took approximately twenty minutes. In the data analysis, the two idea generation steps in each meeting were treated as separate segments. As mentioned in Chapter Three (section 3.5), sections of one meeting can be subdivided and compared using linkography, because the method investigates the internal connections made within such a section. This allows for a paired comparison of the brainsketching and brainstorming with post-its sections within each meeting.

Even though for linkography there is no absolute necessity to isolate the two idea generation steps in one meeting, interaction between the two idea generation steps was reduced as much as possible. First, the task was slightly varied for the first and the second idea generation step. In the first idea generation step the designers
generated ideas for a three-year-old age group, and in the second round the
designers generated ideas for a nine-year-old age group. In this way, in the second
idea generation step, the solution space was slightly altered to reduce building on
the ideas that were generated in the first step, while allowing the designers to still
make use of the information gathered in the briefing and the problem exploration.
Secondly, installing a break between the two idea generation rounds was meant to
take the attention of the designers away from the idea generation task. And, finally,
the flipcharts with ideas that were produced during the first idea generation step
were removed from the view of the participants in order to remove these ideas from
the group’s ‘external memory’ (the concept of ‘external memory’ will be described in
section 5.4).

**Experimental set-up 5.2.6**

All the meetings took place in one afternoon, two meetings in parallel. Meetings
one and two took place in the early afternoon, starting at 1.00 PM, followed by
meetings three and four, which started at 3.30 PM. The meetings were facilitated by
experienced professional creative problem solving facilitators. The meetings took
place in two rooms. The set-up of the two rooms is shown in figure 5.9. Each
meeting was videotaped by means of two cameras set in different angles, in order
to optimize the view for brainsketching and brainstorming.

![Room 1 and Room 2](image)

**Figure 5.9: Room set-up**

The facilitators received a detailed meeting plan, in which their required actions
were explained for each step. In a verbal briefing with the researcher and the two
facilitators, the meeting plan was thoroughly discussed, and there was some fine-
tuning based on the facilitators’ suggestions. In each meeting a research assistant
was present to handle the video cameras, to control the timing, and to provide
directions for the facilitator when needed.

To summarize the experimental design, in table 5.4 an overview of the
experimental set-up is provided, covering the main variables in the meetings:
With the limited number of meetings in this study not all circumstantial variables could be varied across all four meetings. Two combinations were made. First, for all the meetings, in the first idea generation step, ideas were generated for the three-year-old age group and in the second idea generation step ideas were generated for the nine-year-old age group. Secondly, each facilitator worked in the same room for both meetings. This limits the results in that no inferences can be made about whether possible order effects are due to the task used, or to the order of application of techniques, and whether differences in results can be accounted to the facilitator or to the experimental room involved. However, inferences can be made regarding the principal independent variable at stake in the current research question, which is the idea generation technique used. The circumstantial variables are varied in the same way for both the graphic and the sentential condition.

### 5.3 Constructing link matrices

#### 5.3.1 Introduction

The raw data generated by the experimental meetings consisted of videotapes of the meetings, plus the flipcharts with ideas. To recap: During brainstorming with post-its, the designers made short written notations of ideas on large post-it notes with markers. These post-its with ideas were pasted to the flipchart by the facilitator. An example of a brainstorming with post-its flipchart is provided in figure 5.10. During brainsketching, the designers sketched their ideas directly onto the flipcharts that were posted on the wall. Examples of brainsketching flipcharts are provided in figure 5.11.
For each of the eight idea generation segments, the videotape was transcribed into a protocol. Fragments of text that could be appointed to single ideas were selected. Each fragment was given a label that briefly described the idea. The language used in the meetings was Dutch. Examples used in this chapter are translated into English by the researcher. Table 5.5 shows a sample of the thus derived idea fragments of the brainstorming segment in meeting 1. The identification code (I.d.) indicates the designer and the number of the post-it on which the idea was written. As mentioned before, each designer was provided with a booklet of post-its in which each post-it was provided with a number and the designer's identification character. For instance, idea 41 was produced by designer B, who wrote the idea down on his or her 15th post-it note. The time relates to the moment that the designer started verbalizing the idea. Timing was started just before the beginning of the first idea generation segment.

<table>
<thead>
<tr>
<th>No</th>
<th>I.d.</th>
<th>Label</th>
<th>Time</th>
<th>Notation on post-it</th>
<th>Subject explanation of idea</th>
</tr>
</thead>
<tbody>
<tr>
<td>41</td>
<td>B/15</td>
<td>Doll sitting next to child</td>
<td>09.44</td>
<td>Doll for sitting next to you</td>
<td>B: A doll that is sitting next to such a child</td>
</tr>
<tr>
<td>42</td>
<td>D/15</td>
<td>Mini office in the car</td>
<td>09.50</td>
<td>Mini office in the car</td>
<td>D: A mini office in the car</td>
</tr>
<tr>
<td>43</td>
<td>C/14</td>
<td>Mini kitchen</td>
<td>10.05</td>
<td>Playing in a pretend kitchen (mini kitchen)</td>
<td>C: Playing in a pretend kitchen or building such a mini kitchen in the car</td>
</tr>
<tr>
<td>44</td>
<td>D/16</td>
<td>Armrest cuddly toy</td>
<td>10.16</td>
<td>Armrest cuddly toy</td>
<td>D: An armrest cuddly toy</td>
</tr>
<tr>
<td>45</td>
<td>A/11</td>
<td>Animal parts that can be stuck to ceiling</td>
<td>10.23</td>
<td>Velcro/suction cup animal parts</td>
<td>A: All kinds of animal parts that you can stick to the ceiling so that you can combine an animal head with the body of another animal</td>
</tr>
<tr>
<td>46</td>
<td>E/14</td>
<td>Clamp with cuddly toys, musical toys, drawing stuff</td>
<td>10.41</td>
<td>Clamp with cuddly toys, making music, drawing</td>
<td>E: A kind of clamp with which you can do everything, you can make music, drawing, ...[inaudible] ... and that you see in front of you.</td>
</tr>
<tr>
<td>47</td>
<td>B/16</td>
<td>Model head to make-up and do hair</td>
<td>10.50</td>
<td>Head on seat in front (make-up hair dresser)</td>
<td>B: Attach a head to the seat in front, so you can apply make-up and dress the hair.</td>
</tr>
<tr>
<td>48</td>
<td>C/15</td>
<td>Boxing ball with sound effects</td>
<td>11.00</td>
<td>Boxing ball with sound</td>
<td>C: A boxing ball with sound, so that if you hit it then it starts making sounds.</td>
</tr>
<tr>
<td>49</td>
<td>D/17</td>
<td>Seat like papa bear: On papa bear's lap</td>
<td>11.06</td>
<td>(Other) seat: On Papa Bear's lap</td>
<td>D: A seat like papa bear, as if you are sitting on papa bear's lap.</td>
</tr>
<tr>
<td>50</td>
<td>A/12</td>
<td>Ball that sticks to ceiling when thrown</td>
<td>11.19</td>
<td>Ball that sticks to ceiling</td>
<td>A: A ball that sticks to the ceiling when you throw it against it.</td>
</tr>
</tbody>
</table>

Table 5.5: Sample of the idea fragments in the brainstorming with post-its segment of meeting 1.
For the brainsketching segments, the related sketches were added to the fragments. Table 5.6 shows a sample of the idea fragments of the brainsketching segment. The identification code (i.d.) for brainsketching fragments covers the flip chart number, the designer, and the idea number on the flip chart. For instance, idea 44 was sketched on flipchart II by designer C. It was the 10th idea on the flipchart. The time relates to the moment that the designer started sketching the idea.

<table>
<thead>
<tr>
<th>No</th>
<th>i.d.</th>
<th>Label</th>
<th>time</th>
<th>Picture</th>
<th>Subject explanation of Idea</th>
</tr>
</thead>
<tbody>
<tr>
<td>44</td>
<td>IV/10</td>
<td>Seat rises into see-through turret</td>
<td>60.07</td>
<td><img src="image" alt="Image" /></td>
<td>C: I thought in the back, if you make a chair that raises with a button and a turret raises automatically above the roof... that you can look over the whole car, that you can see the signs with city names better, which you can type on a keyboard... that you have some kind of a cockpit.</td>
</tr>
<tr>
<td>45</td>
<td>IV/11</td>
<td>Gun turret</td>
<td>60.27</td>
<td><img src="image" alt="Image" /></td>
<td>D: Yes!... that one (points at idea 44) combined with that one (points at idea 35: virtually shooting other road users) (inaudible) (laughter)... something like a gun turret.</td>
</tr>
<tr>
<td>46</td>
<td>IV/10</td>
<td>Looping race track</td>
<td>59.57</td>
<td><img src="image" alt="Image" /></td>
<td>D: I myself had a looping racetrack... yes, simply this sort of thing which is easier to place into the car (comparing to idea 8: drag-race track). You can put it in front of you and then make laps, racing against each other.</td>
</tr>
<tr>
<td>47</td>
<td>IV/1</td>
<td>Racetrack for planes on roof</td>
<td>61.15</td>
<td><img src="image" alt="Image" /></td>
<td>(written close to idea 5: Racetrack upside down on ceiling)</td>
</tr>
<tr>
<td>48</td>
<td>IV/12</td>
<td>Planes hang on strings so that they glide in bends</td>
<td>81.38</td>
<td><img src="image" alt="Image" /></td>
<td>D: ... and I liked that one very much as well (points at idea 5)... that idea for on the ceiling... and you could do that with little airplanes, because they are in the air anyhow...</td>
</tr>
</tbody>
</table>

Table 5.6: Sample of the idea fragments in the brainsketching segment of meeting 1

For the brainstorming with post-its segments, the idea labels were put into a matrix display in chronological order, which provided the empty link matrix. The links within these link matrices were then filled out following the procedure described in section 3.5. Figure 5.12 shows the link matrix of the brainstorming segment in meeting 1:
In brainsketching, the actual rounds of sketching ideas consist of predominantly individual idea generation activity. To accurately represent the idea generation process, the ideas of the individual designers are positioned next to each other within each round, rather than placing ideas entirely chronologically. This can be done, as the order of occurrence of ideas for the various designers within one round does not influence the basic structure of the link matrix. So, for the brainsketching segments the ideas are organized by round, then by brainsketching sheet, and finally by the order of occurrence for the individual designer. Figure 5.13 shows the thus derived link matrix for the brainsketching segment in meeting 1:

![Figure 5.12: General link matrix of the brainstorming segment in meeting 1. The bold lines provide a reference for each ten ideas.](image)

![Figure 5.13: General link matrix for the brainsketching segment in meeting 1. Bold lines provide a reference for the rounds of generating ideas.](image)
As the brainsketching link matrix is slightly more complicated, a small explanation may be appropriate. Figure 5.14 shows the basic structure of a brainsketching link matrix.

![Figure 5.14: The basic brainsketching link matrix](image)

Links occurring within the triangle-shaped areas adjacent to the diagonal of the matrix (marker 1) refer to connections made with ideas that were generated within that same round of generating ideas. As the brainsketching idea generation process is a predominantly individual activity, it is most likely that self-links occur in this location of the matrix. The links occurring in the box right above the triangle-shaped area (marker 2) refer to connections made with ideas that were explained just before the present round of generating ideas started. Links occurring in any box above the first box (marker 3) refer to connections made with ideas that were generated in the earlier rounds of generating ideas.

### 5.3.2 Reliability

The researcher filled out each link matrix twice, with a time interval of at least one week. The discrepancies between these two link systems were re-evaluated, which provided the final link matrix.

For verification purposes, an observer was asked to fill out a link system for the brainstorming with post-it and brainsketching segments of two meetings, following the same procedure as described in Chapter Three. Inter-rater agreement was determined using Cohen’s Kappa. For the four segments, ‘fair’ to ‘good’ levels of agreement were found between the link systems of the two judges (see table 5.7):

<table>
<thead>
<tr>
<th></th>
<th>Meeting 1</th>
<th>Meeting 1</th>
<th>Meeting 2</th>
<th>Meeting 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Brainstorming with post-its</td>
<td>Brainsketching</td>
<td>Brainstorming with post-its</td>
<td>Brainsketching</td>
</tr>
<tr>
<td>Cohen’s Kappa</td>
<td>0.50</td>
<td>0.69</td>
<td>0.72</td>
<td>0.53</td>
</tr>
</tbody>
</table>

*Table 5.7: Inter-rater agreement*

The differences in Kappas between meetings 1 and 2 may be partly due to the fact that these meetings took place in different laboratories. Meeting 1 took place in a large room where the participants were situated around a semi-circular table.
Meeting two took place in a smaller space with a rectangular table (see figure 5.9). In order to make eye contact during brainstorming with post-its, the participants in meeting 2 needed to make larger physical movements, which were conceived by the judges as evidence for linking. This could explain the higher agreement for the brainstorming with post-its section in meeting two.

The higher Kappa for the first meeting's brainsketching segment may be due to the fact that the larger room allowed a perpendicular view for the video camera, which provided a better overview and therefore clearer indications for links. In meeting 2 the smaller room size required a side-angle camera position. This suggests that indicators for links found in the videotape play a certain role when determining whether or not a link is present between two ideas. In the next chapter, this notion will be further investigated by exploring the types of such 'context' indicators present in the meetings, and the proportion of links that are backed up by context indicators (see section 6.5).

As the Kappa values reach sufficient levels for all four segments investigated, there is no concern for strong differences in link matrices due to the quality of the picture provided by the videotapes.

**Linking in terms of interaction with external memory**

**5.4 Introduction**

The general link indicators developed in Chapter 3 allow the assessment the ways in which idea generation processes meet the guidelines for divergent thinking. The indicators used so far are:

- The **number of ideas** generated has been used as a dependent variable, even though this is not an indicator for linking, because it is a direct indicator of the extent to which the 'striving for quantity' guideline is met.

- The **link density** is an indicator for the degree of integratedness of the process. A high link density indicates that ideas have many connections with earlier ideas. Therefore, the link density is an indicator of the extent to which the participants build on earlier ideas.

- The **self-link index** is the ratio of links that the designers make with their own earlier ideas, divided by their total number of links made. Together with the link density, the self-link index indicates to what extent the 'building on each other's ideas' guideline is met. For the current group size of five designers, a self-link index under 0.2 indicates a 'full' group process (see Section 3.5).

- The **link-type indices** (*Supplementary, Modification, Tangential*) provide indicators for the 'freewheeling' guideline. A high level of tangential links indicates many novel connections made. A low level of tangential links, combined with a high level of supplementary links, indicates early crystallization.
These indicators provide an overview of the general structure of the idea generation process, but they do not address the different functions for the various aspects of the working medium. The working medium used -sketching or writing- may function differently for the individual or the group idea generation process. And, it may function differently for immediate connections made or for the connections that are made with more distant earlier ideas. In order to gain further understanding of the differences in structure between the graphic and the sentential idea generation process, these different aspects of the functioning of the working media need to be addressed by an additional link indicator.

In Chapter 2, the various functions of sketching found in theory were organized by means of an adaptation of Ferguson’s (1992) categorization of types of sketches. According to Ferguson, designers make ‘thinking sketches’ to assist their own individual processes of thought; they make ‘talking sketches’ in support of their discussion; and, they make ‘prescriptive sketches’ to fixate and communicate design decisions. The category of ‘storing sketches’ was added to Ferguson’s three sketch types. Designers make storing sketches as a means of preserving design information (Ullman, Wood, & Craig, 1990). Even though the thus derived categorization into four types worked for structuring the functions of sketches found in the design literature, there are a few problems with it, which limits its use for developing an additional link indicator to help answer the research question at hand.

The first issue with Ferguson’s categorization in relation to the research question is that, as the four types only refer to the working medium of sketches, they do not allow for inclusion of writing as a working medium. If we want to compare the idea generation processes when sketching or written language is used as a working medium, the categorization on which the additional link indicator is based needs to refer to various aspects of the connections made in the group, regardless of the working medium used.

The second issue relates to Ferguson providing a classification of sketches in terms of types of artifacts, which suggests unchanging characteristics. But, Ferguson labels his types by means of the activity for which they are used. A single sketch will often have different functions at different times. For instance, when brainsketching, designers sketch ideas individually. The use of a working medium at the time of generating ideas can be largely considered to be in support of the designers’ own cognitive processes. That could be regarded, in Ferguson’s terms, as a thinking sketch. Then, when the designer explains his or her idea, the thinking sketches all of a sudden turn into a talking sketch. At this time, the sketch is used to support the explanation of the idea. Then, when the new round of generating ideas starts, the sketch turns into a storing sketch. During brainsketching, a single sketch will need to be categorized as three different types at different times (the prescriptive sketch is not as relevant during idea generation meetings, as there is no objective to fixate a certain design alternative). If a single sketch may have
different functions when used in various activities, it may be more informative to
develop a categorization that addresses the designers' different kinds of interaction
with the working medium, rather than providing a categorization of types of
sketches.

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

**External memory according to Newell & Simon**

Newell & Simon (1972) provide a useful basis for this model with their account on
human problem solving. They propose a model of problem solving in terms of
information processing that is based on the -in the field of cognitive science-
commonly adapted dual memory theory. This theory distinguishes a fast but very
limited short-term memory from a slower but basically unlimited long-term memory.
More recent models exist, such as Baddeley's (1986) 'working memory' theory and
Craik & Lokart's (1972) 'levels of processing' theory. The working memory theory
subdivides the short-term memory into a control system, the 'central executive' that
directs a series of servant systems, the most prominent of which are the
'phonological loop', which stores speech-based information, and the 'visuospatial
sketchpad', which sets up and manipulates visual images. Craik & Lokart's levels of
processing theory is also often encountered in textbooks. This theory moves away
from the distinction of different memory types. According to the levels of processing
approach, the durability of an item's storage in memory is based on the depth and
richness in which it was processed. Even though these approaches provide
interesting new insights, they have not been able to replace the current dual
memory standard. The 'working memory' theory merely specifies part of the general
cognitive model, and the 'levels of processing theory' has not succeeded in gaining
sufficient empirical evidence. According to Phillip & Baddeley (1989), this approach
"...stimulated a great deal of rather fruitless research during the 1970s, and has
proved to be a useful rule of thumb, but has proved rather fruitless in generating
further theoretical development" (p. 66).

According to Phillip & Baddeley, over the years a wide body of empirical evidence
has accumulated for the dual memory theory, as well as a variety of proposed
models, the most influential of which by Atkinson & Shriffin (1968). Because Newell
& Simon (1972) came to cognitive science from the domain of artificial intelligence

*study two*
rather than psychology, their model of human problem solving differs from other models by including the problem solver's external workspace in their model as, what they call, an 'external memory'. Their model is especially interesting for design research, as the interaction with the drawing (or writing) surface is regarded instrumental to design problem solving (see Purcell & Gero, 1998, for a review of theories on drawing and the design process). Newell & Simon's human problem solving model has a central role in design methodology (Dorst, 1997) and is applied as a basic model in design thinking research (e.g. Ullman et al, 1990).

The human information processing system according to Newell & Simon, consists of the following main elements: long-term memory, short-term memory, elementary information processes, and external memory. Here, only the issues related to their description of external memory are covered. For a thorough description of all the elements of the information processing system, we refer to Newell & Simon's original work (see pages 791-809 for a description of the fundamental characteristics of the human information processing system).

Newell & Simon do not make a distinction between the internal short-term memory and the medium that a subject is working on:

- From a functional viewpoint, the STM (Short-term memory) should be defined, not as an internal memory, but as the combination of (1) the internal STM (as measured by the usual psychological tests), and (2) the part of the visual display that is in the subject's foveal view. The latter augmentation of the short-term store is, of course, a read-only memory. But it increases the short-term capacity and enhances the stability of the memory considerably. (p. 801)

According to them, the part of external memory that is in the direct view of the subject provides an integral part of the short-term memory, and can be seen as an extension thereof. However, the external memory is not as immediately available as the internal short-term memory.

- ... EM (External memory), like LTM (Long-term memory) must be deliberately accessed for both reading and writing. EM, like LTM, is essentially infinite in capacity. However, it is not associative, but rather must be accessed by means ranging from linear scanning to random accessing from addresses held in STM. It takes a few hundred milliseconds either to read from a fixated domain to STM or to perform a saccade to another arbitrary point in the visual field. Thus, reading either from located domains of EM or from LTM requires time of the same order of magnitude. (p. 801-802)

Reading from external short-term memory takes time, of the same order as the time required for retrieving information from the long-term memory. But, external memory has a strong advantage over long term memory. According to Newell & Simon, storing information in external memory is much faster: "The time to record a
new structure in an appropriate EM tends to be much shorter than the time (five to ten seconds) required to record new symbols in LTM” (p. 802). Consequently, the external memory provides a good alternative for the long-term memory.

Newell & Simon make a distinction between external memories that are in the direct view of the subject, which the above refers to, and more distant external memories which require more effort to access:

There are, of course, more remote EM’s, such as the work sheet on the side of the table, the sheet under the sheet now being worked on, nearby books, books in the library, and so on. Accessing times become increasingly large as more extensive motor behavior and physical distance are involved in retrieval (p. 802).

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

The term short-term suggests a relation to time rather than to the location of the idea, which could be confusing if we apply this term to external memory, in which the immediate area is identified by the location of the idea. To avoid confusions, we will use the term ‘direct’ external memory, rather than ‘short-term’ external memory to refer to the ideas that are immediately available to the designer. Figure 5.15 provides a model of an individual designer’s interaction with his or her external memory.

Before being able to interact with a notation in the remote part of external memory, the designer transfers the notation into the direct part of external memory. When a notation in the remote part of external memory is found, it enters the direct view of the designer, which is how the direct part of external memory is defined. And, as notations can only be made within the direct part of external memory, any notation in the remote part of external memory made by the designer needs to first be part of the direct part of external memory.

**Interaction with external memory in design groups**

5.4.3

The model of a designer’s interaction with notations in his or her external memory can be extended towards group problem solving, when regarding groups as interacting human information processing systems. Interaction between group members takes place through verbal or gestural communication, and through the group’s external memory. The group’s external memory consists of the combined external memories of the individuals. Some parts of the group’s external memory belong to the individual group members, for instance notes written by a group.
member in a personal notebook. Other parts of the group’s external memory are shared, for instance, when a group member makes marks on a whiteboard while the other group members are watching. Then, this information becomes available to all group members present. As described earlier, the individual external memory consists of direct parts and remote parts. Analogous to the individual parts, the shared parts of the group’s external memory can be sub-divided into direct parts and remote parts. The direct-shared parts of the group’s external memory may consist of notations that are made in support of the discussion on a whiteboard, or the flipchart used by a facilitator to record options while brainstorming. The shared-remote parts of the group’s external memory may consist of notations on flip charts that are posted away from the direct view of the group members. Figure 5.16 shows the four parts of external memory available to a group member.

If a designer is working by himself, and makes notes on a sheet of paper, then he/she is exchanging information with the individual direct part of external memory (marker 1). When the designer turns to a new sheet of paper -or, for instance, to a different location on the present sheet- this information then becomes part of the individual remote part of external memory (marker 2). If, at a later point in time, the designer revisits this sheet of paper, the information re-enters his/her direct vision, and consequently the information re-enters into the individual direct part of external memory (marker 3).

If a designer is working together with other designers on a sheet of paper, then he/she is exchanging information with the shared direct part of external memory (marker 4). When the designers then turn to a new sheet of paper, this information moves into the shared remote part of external memory (marker 5). If, at a later point in time, the designer revisits this sheet, the information re-enters the shared direct part of external memory (marker 6). One might argue that in this case the designer takes information from the shared remote part into the individual direct part of external memory, instead of the shared direct part. However, as interaction with one’s own sketches and writing may be structurally different from interaction with someone else’s sketches and handwriting, for pragmatic reasons the individual external memory is regarded to only consist of information that is entered by that individual. Whenever a designer uses information that was entered by another designer, that information becomes part of the shared external memory.

Sometimes, information that was entered into the individual external memory can transfer to the shared external memory (marker 7). This can happen deliberately, for instance, a group member may make a notation individually, and then explain the notation to the group. In that case, the group member first interacts with his individual direct part of external memory. As he presents the diagram to the other group members, the information transfers to the shared direct part of external memory. From there it may move to the shared remote part of external memory. Information transfer from the individual to the shared external memory can also
occur unsolicited. For instance, a designer may be making private notes in his notebook, without being aware that another group member is watching over his shoulder.

An example of interaction with external memory

Based on information processing theory, we have constructed a model of the interaction of design groups with the various parts of external memory that is independent of the working medium used. Also, it focuses on the activities that take place in interaction with the working media, rather than on the artifacts produced. We still need to verify whether the theoretical model is functional in describing the interactions with external memory for real design groups. Therefore, we explored the different interactions in the group protocol of the Delft Protocols Workshop (Cross, Christiaans, & Dorst, 1996). This Delft protocol consists of a two-hour design simulation with a team of three experienced product designers. In the protocol, the designers are given fictional names: Ivan, John, and Kerry. The assignment for the group is to design a carrying or fastening device for a backpack onto a mountain bike. The media for recording are markers, a whiteboard and large worksheets on the table. For a thorough description of the experiment we refer to the proceedings of the Delft Protocols Workshop (Cross, et al, 1996). Here we will map the interactions made with a single design sketch onto the model of the four parts of a group's external memory to exemplify the different interactions in which a single sketch can be involved.

About 40 minutes into the two-hour design meeting, Ivan is writing down a list of options for 'joining concepts', Kerry sketches the locations of the structural components in the design problem: the bicycle, the rack and the backpack. There is no indication that, at this time, the other two designers notice this sketch. Then, she joins John and Ivan in generating ideas for the backpack-rack connection, which means that her sketch moves from Kerry's individual external direct memory to her individual remote memory. About twenty minutes later, after discussing existing bicycle racks, she draws in a wire frame to connect the rack to the bicycle. Again, this is an individual activity, which means that she retrieved her sketch from individual remote memory into her individual external direct memory (see figure 5.17).

Figure 5.17: Kerry's initial (0h40) sketch of the structural components in the design task: bicycle, rack and the backpack (represented by a box-shape in the drawing), followed by the wire frame she included to support the rack (1h01). The graph on the right provides an overview of the transfers of information that have taken place up to this point.
Right after Kerry sketches the three-legged wire-frame into her drawing, John notices Kerry's idea. He starts drawing an option into kerry's sketch of using just one support tube, instead of three, in order to provide adjustability for different bike sizes (figure 5.18). He says: "...you know, one way just to build on your idea a little bit ... one way to get that adjustability for the seat post height and all that stuff is if this, say this was a single bar and it went like this..." (1h02). At this instance, Kerry's sketch becomes part of the shared direct part of external memory.

At a later moment in the design meeting, the team decides that they have a basic design solution and that now it is time for some more detailed designing. John says: "so let's get some dimensions on this turkey and er detail drawing phase" (1h38). Ivan takes the worksheet and pastes it to the whiteboard (figure 5.19). The information on this flipchart shifts from the designers' direct visual display towards a more distant location. This means that the sketch makes a final transition from the shared direct to the shared remote part of the external memory.

The suggested model of the designers' interactions with the four parts of external memory overcomes the two limitations to the earlier categorization made. As it is a general model for notations in external memory, it allows for comparing the working media of sketching and writing. And, as it is a model of interactions rather than notation types, it encompasses the changing nature of the designers' interactions with their notations in external memory. The model describes how Kerry's initial sketch of the structural components of the design task is used in a variety of different activities. In the earlier categorization based on Ferguson's sketch types,
the sketch would have shifted identity a number of times, from being a thinking sketch, to storing sketch, then back to thinking sketch, then talking sketch, and finally a storing sketch. The characteristics of the sketch do not usually change; the interactions with the sketch change. Therefore, the model of the design group's interactions with their notations in the four areas of external memory provides a more useful model for organizing the functioning of the working media.

The interactions with external memory in idea generation group meetings can be described accordingly. Typically, for brainstorming with post-its (Isaksen, Dorval, & Treffinger, 1994), participants write down their ideas on post-it notes, then explain their ideas to the group, whereupon the facilitator pastes the ideas on a flipchart. A brainstorming with post-its idea is at first located in a group member's individual direct part of external memory. When the group member explains the idea and the facilitator pastes it onto the flipchart, the idea transfers into the shared direct part of the external memory. Then, when direct focus of the group moves away from the idea, the idea becomes part of the shared remote part of external memory. As a group member revisits the idea, the idea re-renters the shared direct part of external memory. For brainsketching, the typical trajectory of ideas through the external memory is basically the same. Figure 5.20 shows the typical flow of information through the four parts of external memory for both idea generation techniques.

**Link densities for the four external memory types**

Within a link matrix link densities can be determined for the various parts of the group's external memory, which provide an indicator for the extent to which brainstorming and brainsketching make use of the different parts. The distinction between the individual and the group aspects of the external memory are provided in a matrix by the self-links and the interpersonal links (see section 3.5). An operationalization for the distinction between the direct and the remote aspects still needs to be made.

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

For the brainsketching segments, the direct linking area can be considered to contain the ideas that were explained just before the current round of generating ideas started, plus the ideas that the designer is generating him- or herself during the present round of sketching ideas.
Below, the link matrix for the brainsketching segment in meeting 1 is divided into a direct and a remote area (see figure 5.21):

![Link Matrix](image)

**Figure 5.21**: Link matrix for the brainsketching segment in meeting 1. Links in the shaded areas represent interaction with the direct part of external memory. Black squares refer to interpersonal links and crosses refer to self-links. Whitened areas refer to unlikely link locations.

During brainsketching, the designers generate ideas in parallel. Therefore, it is not likely that there are direct links between ideas generated by different designers within the same round of generating ideas. The designers may sometimes take a peak at the flipcharts of their neighbors, but this was found to occur rarely. In the brainsketching link matrices the areas where linking is highly unlikely to occur are whitened. Of course, within each round of generating ideas, designers can build on their own recently generated ideas, as represented by the single, or small triangular groups of potential link locations at the diagonal of the link matrix.¹

For brainstorming with post-its the generation of ideas is a continuous group process, which makes it more complicated to provide an operationalization for the direct linking areas in the link matrix more difficult to define. As for brainsketching, the direct linking area ought to cover the link locations with ideas that are still present in the focus of attention. This number needs to be more than seven, because that is supposed to be the average amount of ideas or chunks that the internal short-term memory can contain (Miller, 1956). The external notations are supposed to provide an extension to the short-term memory and therefore should contain more than these seven ideas. It cannot be much more than seven ideas, however, because the human attentional focus can only cover a limited number of items (e.g. Pashler, 1995). We made the assumption that the direct linking area for the brainstorming segments contains the link locations with the ten previous ideas. The actual direct area may contain a few ideas more or a few ideas less, but the results do not change dramatically when the bandwidth is made a few link locations narrower or wider.
Figure 5.22 provides a representation of the ten-ideas wide direct linking bandwidth within the link matrix of the brainstorming segment of meeting 1. Just as in the brain sketching link matrices, the shaded area marks the direct linking area, the darkened boxes stand for interpersonal links and the crossed boxes stand for self-links.

![Image of a matrix representing linking with four external memory types within the link matrix of the brainstorming segment of meeting 1. The black squares stand for interpersonal links and the crossed squares stand for self-links. Links within the shaded area indicate linking with the direct aspects of the group's external memory. Links outside of this area indicate linking with the remote aspects of the group's external memory.]

Now, for each of the areas of external memory the link density can be determined. Individual direct links are represented by the self-links within the shaded areas in the link matrices. The shared direct links are represented by the interpersonal links within the 10-idea bandwidth. The individual remote links are represented by the self-links outside of the 10-idea bandwidth, and, finally; the shared remote links represented by the interpersonal links outside of the 10-idea bandwidth. Thus, in the brainstorming segment of meeting 1 these are:

- Individual direct links = 11
- Individual remote links = 8
- Shared direct links = 27
- Shared remote links = 20

The link density for each external memory type can be determined by dividing the number of links found for each external memory type by the total number of ideas in the meeting. The link densities allow for comparison of the use of external memory types across the various meetings. In total 72 ideas were generated in the brainstorming segment of meeting 1. This gives the following link densities for the external memory parts:
\[ LD_{\text{INDIVIDUAL, DIRECT}} = \frac{11}{72} = 0.15 \]
\[ LD_{\text{INDIVIDUAL, REMOTE}} = \frac{8}{72} = 0.11 \]
\[ LD_{\text{SHARED, DIRECT}} = \frac{27}{72} = 0.38 \]
\[ LD_{\text{SHARED, REMOTE}} = \frac{20}{72} = 0.28 \]

In a similar fashion, the link densities for the external memory areas can be determined for the brainsketching segments. When analyzing the data, for each of the twenty participating designers, their link densities with the four memory types were calculated by taking each designer's links in the four parts of external memory, and dividing it by the number of ideas generated by the designers. The mean scores for each part of external memory were then compared between the brainsketching and brainstorming conditions.

5.5 Results

5.1 General results
The link matrices for the four brainstorming and the four brainsketching segments are provided below (figures 5.23-5.30). Only the idea labels in the two link matrices of meeting 1 are translated into English. For the other link matrices, the idea labels are in Dutch.
Figure 5.23: Link matrix meeting 1 brainstorming. In meetings 1 and 2, brainstorming was applied in the first idea generation step. Most of the links are made within the direct diagonal bandwidth while there is also linking happening with the first few ideas throughout the segment (identical to fig. 5.22).

Figure 5.24: Link matrix meeting 1 brainsketching. Some self-linking is taking place along the diagonal, and there are interpersonal links in a band slightly removed from the diagonal. These are links with ideas that were just explained by the designers (identical to fig. 5.21).
Figure 5.25: Link matrix meeting 2 brainstorming. This meeting is signified by a very large number of ideas generated. As in the brainstorming segment of meeting 1 most linking takes place within the direct bandwidth along the diagonal.

Figure 5.26: Link matrix meeting 2 brain sketching. Apart from the diagonal line of linking with the ideas that were just mentioned, there appears to be a second diagonal line of linking just above the direct linking zone. Most of these more remote links are between ideas that were sketched on the same flipchart.
Figure 5.27: Link matrix meeting 3 brainstorming. In meetings 3 and 4 brainstorming with post-its was applied in the second meeting step. There appears to be relatively limited linking taking place in this brainstorming segment. Again, most linking takes place within the direct bandwidth. The linking in the remote area in the second half of the segment is almost non-existent.

Figure 5.28: Link matrix meeting 3 brainsketching. The linking taking place appears to be more spread throughout the matrix. In the final two rounds of idea sketching especially many connections with earlier ideas are made.
Figure 5.29: Link matrix meeting 4 brainstorming. As in meeting 3, brainstorming was applied in the second idea generation step. The most remarkable aspect about this meeting is the low number of ideas generated. In the brainstorming segment of meeting 2, almost twice as many ideas were generated.

Figure 5.30: Link matrix meeting 4 brainsketching. As well as the linking along the diagonals mentioned before, there appears to be a lot of linking taking place in the last round of idea sketching. Also, throughout the segment the first few ideas are used regularly for linking.
For each of the designers the link indicators for both the brainstorming and the brainsketching condition were determined based on the link matrices. Table 5.8 provides an overview of the general results thus derived.

<table>
<thead>
<tr>
<th>Designer</th>
<th>Number of ideas</th>
<th>Link density</th>
<th>Self link index</th>
<th>Number of ideas</th>
<th>Link density</th>
<th>Self link index</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>11</td>
<td>1.09</td>
<td>0.25</td>
<td>11</td>
<td>0.82</td>
<td>0.33</td>
</tr>
<tr>
<td>B</td>
<td>15</td>
<td>0.73</td>
<td>0.18</td>
<td>5</td>
<td>1.60</td>
<td>0.25</td>
</tr>
<tr>
<td>C</td>
<td>14</td>
<td>0.79</td>
<td>0.09</td>
<td>6</td>
<td>1.13</td>
<td>0.22</td>
</tr>
<tr>
<td>D</td>
<td>19</td>
<td>0.79</td>
<td>0.47</td>
<td>15</td>
<td>1.20</td>
<td>0.39</td>
</tr>
<tr>
<td>E</td>
<td>13</td>
<td>1.31</td>
<td>0.35</td>
<td>12</td>
<td>1.08</td>
<td>0.54</td>
</tr>
<tr>
<td>F</td>
<td>23</td>
<td>0.70</td>
<td>0.44</td>
<td>8</td>
<td>1.13</td>
<td>0.11</td>
</tr>
<tr>
<td>G</td>
<td>14</td>
<td>1.14</td>
<td>0.19</td>
<td>10</td>
<td>1.00</td>
<td>0.30</td>
</tr>
<tr>
<td>H</td>
<td>19</td>
<td>0.55</td>
<td>0.28</td>
<td>10</td>
<td>1.20</td>
<td>0.08</td>
</tr>
<tr>
<td>J</td>
<td>16</td>
<td>0.81</td>
<td>0.00</td>
<td>13</td>
<td>1.54</td>
<td>0.30</td>
</tr>
<tr>
<td>K</td>
<td>13</td>
<td>0.69</td>
<td>0.00</td>
<td>10</td>
<td>1.40</td>
<td>0.36</td>
</tr>
<tr>
<td>L</td>
<td>10</td>
<td>0.40</td>
<td>0.25</td>
<td>8</td>
<td>1.38</td>
<td>0.18</td>
</tr>
<tr>
<td>M</td>
<td>16</td>
<td>0.59</td>
<td>0.45</td>
<td>10</td>
<td>1.10</td>
<td>0.18</td>
</tr>
<tr>
<td>N</td>
<td>7</td>
<td>1.14</td>
<td>0.25</td>
<td>9</td>
<td>1.11</td>
<td>0.30</td>
</tr>
<tr>
<td>O</td>
<td>14</td>
<td>0.64</td>
<td>0.33</td>
<td>10</td>
<td>1.10</td>
<td>0.18</td>
</tr>
<tr>
<td>P</td>
<td>13</td>
<td>0.92</td>
<td>0.17</td>
<td>11</td>
<td>0.91</td>
<td>0.70</td>
</tr>
<tr>
<td>Q</td>
<td>11</td>
<td>0.82</td>
<td>0.44</td>
<td>6</td>
<td>2.00</td>
<td>0.25</td>
</tr>
<tr>
<td>R</td>
<td>11</td>
<td>0.55</td>
<td>0.33</td>
<td>11</td>
<td>0.82</td>
<td>0.56</td>
</tr>
<tr>
<td>S</td>
<td>9</td>
<td>0.67</td>
<td>0.17</td>
<td>8</td>
<td>1.13</td>
<td>0.44</td>
</tr>
<tr>
<td>T</td>
<td>6</td>
<td>1.17</td>
<td>0.43</td>
<td>8</td>
<td>1.63</td>
<td>0.31</td>
</tr>
<tr>
<td>U</td>
<td>7</td>
<td>0.86</td>
<td>0.00</td>
<td>9</td>
<td>2.11</td>
<td>0.32</td>
</tr>
</tbody>
</table>

**Table 5.8: General link indicators for the individual designers for the brainstorming and brainsketching conditions.**

The significance of the differences in means were determined using a paired comparison t-test in SPSS 10. The results are provided below.

**Number of ideas**

![Graph showing mean numbers of ideas](image)

**Figure 5.31: Mean numbers of ideas (per designer) for brainsketching and brainstorming. Error bars show the 95% confidence interval for the mean values.**
The average number of ideas generated by the participants (figure 5.31) while engaged in brainstorming with post-its ($\bar{x}=13.05$, $SD=4.32$) is significantly ($p<0.005$) higher than the number of ideas generated while engaged in brainsketching ($\bar{x}=9.60$, $SD=2.30$). By having a higher idea production, brainstorming with post-its complies better with the 'striving for quantity' guideline of divergent thinking.

5.5.3 Link density

![Figure 5.32: Mean link density for brainsketching and brainstorming](image)

The mean link density (figure 5.32) is significantly ($p<0.0005$) higher for the brainsketching condition ($\bar{x}=1.27$, $SD=0.35$) compared to the brainstorming condition ($\bar{x}=0.84$, $SD=0.23$). By having a higher level of linking between ideas, brainsketching complies better with the 'building on each other's ideas' guideline for divergent thinking.

To inspect the way in which the linking process develops over the segments, within the brainsketching and the brainstorming segments the link densities for each section of ten percent of ideas generated were determined. To provide a general progress for the brainsketching condition, the mean was taken for the four segments. Figure 5.33 provides a graphic display of the progression of the link density for the brainstorming and for the brainsketching conditions.
For the brainstorming technique, the link density progresses gradually until halfway through the segment. Then it declines to approximately the average value of the link density. In the first half of the segment, the link density also increases for brainsketching. In contrast to brainstorming, the link density keeps increasing in the second half, with a high value of a link density of 3.2 in the final section (between 90-100% of the ideas generated).

The growth of the link density in the first half for both techniques may be explained by the increasing number of source ideas that are available. For brainsketching, this appears to be true for the second half as well; when more source ideas become available in the brainsketching segments, the link density grows. This explanation does not account for the decline of the link density in the second half for the brainstorming condition.

Overviews of the evolution of the link type indices over the progress of the meeting segments for the brainsketching and brainstorming conditions follow later.

Self-Link Index 5.5.4

The average self-link indices for both brainsketching and brainstorming with post-its (see figure 5.34) are slightly above the ‘full group process’ level which, for a group with five participants, is signified by a self-link index of 0.2 or lower. The difference in means is not significant, but the self-link index for brainsketching tends to be slightly higher ($x=0.32; SD=0.15$) than the self-link index for brainstorming ($x=0.25; SD=0.15$). This suggests that the brainsketching process is slightly more individually focused than brainstorming with post-its.
5.5.5 Link type indices

The link type indices show the ways in which participants build on earlier ideas. A high level of supplementary links indicates gradual improvement; a single concept is refined and developed. A high level of modification links indicates an idea generation process that is based on direct association; there is variation within a general direction of search. And, a high level of tangential links indicates an idea generation process based on opening up new search directions; source ideas are used as springboards towards different directions. Figure 5.35 shows the mean link type indices for the brainsketching and for the brainstorming conditions.

The mean supplementary link type index is significantly ($p<0.01$) higher for brainsketching ($x=0.25; SD=0.15$) compared to brainstorming ($x=0.11, SD=0.11$). The mean modification link type index is significantly ($p<0.05$) lower for brainsketching ($x=0.44; SD=0.14$) compared to brainstorming ($x=0.53; SD=0.15$). No significant difference was found for the tangential link type index between brainsketching ($x=0.31; SD=0.15$) and brainstorming ($x=0.36; SD=0.17$).

In section 5.2 we pointed out that the revision made to brainsketching could lead to a low level of tangential linking. If that were the case, interactive brainsketching could not be considered a suitable representative of graphic idea generation techniques. In the current study, no such low level of tangential linking was found for interactive brainsketching, which means that we can maintain the technique as a representative of graphic idea generation techniques.

Brainstorming with post-its appears to be strongly based on exploration of search directions through modification-type linking, complemented by the opening up of
new search directions through tangential-type linking. Little idea refinement—signified by supplementary linking—takes place during brainstorming with post-its.

Brainsketching encompasses all types of linking. This could mean that new directions are opened up through tangential-type linking, then these directions are explored through modification-type linking, and subsequently ideas are developed through supplementary-type linking. To investigate whether this is the case, the occurrence of links of the various types throughout the segments are determined. Figure 5.36 provides an overview of the average number of S(supplementary), M(modification), and T(tangential) links per idea occurring in the brainsketching segments for each ten percent of ideas generated.

![Figure 5.36: Mean progress of the link type indices for the four brainsketching segments.](image)

In the first part (first 40%) of the brainsketching meetings, there appears to be a balance between modification and tangential links. Then, modification links become more dominant. From 40% on, the supplementary links start to play a part in the idea generation process. The last ten percent of the meetings have an emphasis on idea refinement through a high amount of supplementary linking. This may be explained by the notion that in the final part of the segments, participants can run out of ideas. As is customary in practice, the facilitators were asked to overcome this by reinforcing the 'building on each other's ideas' guideline in the end of the segments, both for brainsketching and for brainstorming. Figure 5.37 shows the graph of the average number of S, M and T links per idea for the brainstorming with post-its segment.
This graph indicates a different type of idea generation process. Evidently, the overall level of linking is lower than for brainsketching. Besides that, an idea generation process is detected where throughout the process, supplementary links are hardly present. Modification linking is most dominant in most of the brainstorming with post-its process. Tangential-type linking is strongly present as well, especially in the early 20% of the meetings. The final 20% of the meetings are dominated by modification-type linking, with the tangential-type linking fading away.

5.5.6 Interaction with the four parts of the group’s external memory
The final analysis performed consisted of determining the interactions with the four identified parts of the external memory (see section 5.4). The group’s external memory consists of the notations made during the meeting. The linking with ideas located in the external memory of a group can be sub-divided into four types, corresponding with the four areas of the external memory. As described in section 3.5, a connection that a designer makes with an earlier idea of his/her own is an individual- or self-link. A connection made by a designer with an earlier idea produced by one of the other designers is a shared- or interpersonal link. Direct links are connections made with the immediately preceding ideas, which are assumed to be part of the direct visual display of the designers. Remote links are links with ideas that are outside of the direct visual display. This lead to four types of links: individual direct links, individual remote links, shared direct links and shared remote links.

The link densities for the individual memory types provide a specification of the general link density (which was shown in figure 5.32). The participants’ (n=20) mean link densities for the four parts of external memory are shown in figure 5.38.
In both the brainsketching and the brainstorming with post-its segments, participants link primarily with ideas in the direct interpersonal component of external memory (for brainsketching, $\mu=0.53$, $SD=0.22$; for brainstorming, $\mu=0.43$, $SD=0.17$). For both techniques, participants scarcely link with ideas in the individual remote memory (for brainsketching, $\mu=0.13$, $SD=0.12$; for brainstorming, $\mu=0.09$, $SD=0.09$).

There is a significant difference between the two techniques for linking with ideas in the external direct memory ($p<0.005$). During brainsketching, participants regularly link with ideas in the individual direct area of external memory ($\mu=0.26$; $SD=0.13$). For brainstorming with post-its, the mean link density for this area does not even reach half that value ($\mu=0.12$; $SD=0.10$). Apparently, making connections with their own, most recently generated ideas is an essential part of the participants’ idea generation process while brainsketching.

The other significant difference found between brainsketching and brainstorming with post-its concerns the linking with ideas in the remote interpersonal area of external memory ($p<0.05$). When brainsketching, participants make significantly more connections with ideas in the remote interpersonal area (or brainsketching, $\mu=0.35$, $SD=0.22$; for brainstorming, $\mu=0.20$; $SD=0.18$). When brainsketching, the designers tend to integrate information gained by the generation of earlier ideas into the present idea generation process.

This indicates that brainsketching allows for an individual idea generation process that is characteristic of the idea sketching process (as discussed in Chapter Two), while at the same time integrating earlier knowledge generated by the group.
5.6 Discussion: Typical idea generation processes for brainstorming and brainsketching

5.6.1 Introduction

The main question to be answered in this study is:

*What are the differences in the structure of the idea generation processes, when sketching or written language is used as a working medium?*

Many differences were found for the various link indicators. Table 5.9 shows a concise overview of these differences:

<table>
<thead>
<tr>
<th></th>
<th>Brainsketching</th>
<th>Brainstorming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of ideas</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Link density</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Link type indices</td>
<td>T → M → S</td>
<td>M ↔ T (S)</td>
</tr>
<tr>
<td></td>
<td>(Progress from predominantly tangential links to predominantly modification links to predominantly supplementary links)</td>
<td>(Mostly modification- and tangential linking. Hardly any supplementary (linking))</td>
</tr>
<tr>
<td>Link densities for external memory:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Individual direct</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Individual remote</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Shared direct</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Shared remote</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>

*Table 5.9: Overview of the differences in link indicators between the brainsketching and the brainstorming conditions. Pluses and minuses refer to relative performance for the working medium.*

The designers produced a significantly higher number of ideas when brainstorming, in comparison to brainsketching. During brainsketching, designers produce ideas that have significantly more connections with the earlier ideas. This means that brainstorming with post-its complies better to the ‘strive for quantity’ guideline for generating ideas, and brainsketching complies better to the ‘build on each other’s ideas’ guideline.

The linking with the various areas of the external memory showed that, during brainsketching, the generated ideas have significantly more connections with the individual direct part of external memory and with the shared remote part of external memory. This means that for brainsketching, making connections with one’s own most recently generated ideas is more relevant than for brainstorming, while, at the same time, the ideas that were generated earlier by other group members are also more relevant for brainsketching for making connections. For brainstorming, the shared direct part of external memory appears most relevant for making connections with.
From the link type indices we learned that during brainsketching designers make more supplementary connections, which are hardly present in the brainstorming segments. These incremental steps do not mean that there is a lower proportion of tangential connections made. In that sense, brainsketching appears to entail a more balanced problem solving process. Brainstorming consists primarily of modification-type links, interspersed with tangential-type links.

The differences in the idea generation processes become clearer when inspecting the variations in types of linking throughout the progress of the segments. Figure 5.37, which presents the mean link type indicators for each ten percent of ideas generated in the brainstorming segments, shows that the brainstorming process quickly reaches a mature condition, in which the levels of tangential and modification links are more-or less balanced. The development of the link types in the brainstorming condition suggest a process of continuous inspection for, and exploration of, new search directions. In the brainstorming condition, throughout the meetings, few idea development steps take place, as signified by the low level of supplementary linking.

During brainsketching (see figure 5.36), there appears to be a development from tangential linking in the first part of the meeting, to modification-type linking in the middle, with a focus on supplementary-type linking in the end. The development of the link types over the progress of the meetings suggest that during brainsketching, designers make connections in accordance with the ways in which design processes are typically described. Usually design processes are marked by a broad search in the beginning leading to specific improvements of concepts in the later parts of the process. For instance, Goel (1995) investigated the types of transformations taking place in several design protocols. He defined two types of transformations: 'lateral transformations', which indicates movement from one idea to a different idea, and 'vertical transformations', which indicate movement from one idea to a more detailed version of the same idea. According to Goel, "the data indicate that lateral transformations are generally confined to preliminary design phases whereas vertical transformations generally occur in the refinement and detailing phases" (p.121). He identified an incremental movement in the protocols, starting with an emphasis on 'lateral transformations' that broaden the problem space in the beginning of the design process, and ending with an emphasis on 'vertical transformations' in the later phases of the design process. If we associate tangential-type linking with lateral transformations, and supplementary-type linking with vertical transformations, then the general progression of the link types in brainsketching is much like Goel's movement of transformations in the design process. To conclude this empirical chapter, and to illustrate the different types of idea generation processes when sketching or writing is used as a working medium, typical moments in the experimental idea generation meetings are described for each technique.
5.6.2

A typical example of the brainsketching idea generation process

Brainsketching tends to stimulate a design-like idea generation process. Such a design-like process is signified by a general movement from wild leaps in different directions in the initial ideas generated, via exploration of some of these directions, towards small incremental steps in the final ideas.

This movement can also be found when tracing back the linking that lead to the final brainsketching ideas. As an example, we will retrace the linking that lead towards idea 48 in the brainsketching segment of meeting 1, which was generated by designer D (see figure 5.39, and fig. 5.24 for the link matrix of this segment).

The idea consists of fitting a racetrack for model airplanes on the ceiling of the car. The airplanes are suspended on wires so that they go through the turns in an angle, as real airplanes do. Figure 5.40 shows the chart on which this idea was sketched, and table 5.10 provides a selection of idea fragments from the protocol that are discussed in the example:

![Diagram of brainsketching meeting 1 idea 48, a racetrack for planes on ceiling with planes suspended on strings so that they glide in turns, as real planes do](image)

![Meeting 1 brainsketching flipchart III](image)
<table>
<thead>
<tr>
<th>No</th>
<th>I.d.</th>
<th>Label</th>
<th>time</th>
<th>Picture</th>
<th>Subject explanation of idea</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>III/C/1</td>
<td>Winch with remote control suspended from roof</td>
<td>36.43</td>
<td><img src="image" alt="Electric winch with grab on ceiling" /></td>
<td>C: That is kind of a winch on the ceiling, with some kind of a rail... that you can grab all kinds of things on the back seat with some kind of a remote control... so that you can let it go from one side to the other... That you can lower it and grasp things with your grab.</td>
</tr>
<tr>
<td>5</td>
<td>III/C/2</td>
<td>Racetrack upside down on roof</td>
<td>37.44</td>
<td><img src="image" alt="Racetrack on roof (upside down)" /></td>
<td>C: And some kind of race track on the roof... so that you can look at the ceiling, and so there are cars that stick to the ceiling that make laps.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>C: Yes, this is drawn a bit awkwardly</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>D: So, they... just on the ceiling</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>C: Yes, simply against the ceiling, so that the cars drive upside down</td>
</tr>
<tr>
<td>17</td>
<td>III/B/0</td>
<td>Miniature train track around back seats</td>
<td>42.08</td>
<td><img src="image" alt="Train track" /></td>
<td>B: Well, that is building a little bit on his idea (points at idea 5C), to have a train track through the entire interior... perhaps its best to only have it in the back, over the back shelf, and...</td>
</tr>
<tr>
<td>46</td>
<td>III/D/0</td>
<td>Looping race track</td>
<td>59.57</td>
<td><img src="image" alt="Looping race track" /></td>
<td>D: I myself had a looping racetrack... yes, simply this sort of thing which is easier to place into the car (compares to idea 8: drag-race track). You can put it in front of you and then make laps, racing against each other.</td>
</tr>
<tr>
<td>47</td>
<td>III/D/1</td>
<td>Racetrack for planes on roof</td>
<td>61.15</td>
<td><img src="image" alt="Racetrack upside down on ceiling" /></td>
<td>D: ... and I liked that one very much as well (points at idea 5)... that idea for the ceiling... and you could do that with little airplanes, because they are in the air anyhow...</td>
</tr>
<tr>
<td>48</td>
<td>III/D/1</td>
<td>Planes hang on strings so that they glide in bends</td>
<td>61.38</td>
<td><img src="image" alt="Planes glide in bends" /></td>
<td>D: ... and you could align them nicely in two tracks next to each other and hang them from a string so that they really glide in the bends</td>
</tr>
</tbody>
</table>

| Table 5.10: Selection of the protocol: ideas on flipchart III related to idea 48, racetrack for airplanes |

In the first round of generating ideas, designer C sketches an idea of a winch suspended from the ceiling that can be operated by remote control (idea 4). This idea brings the roof to his attention as a location for toys. He then generates an idea of a racetrack for cars, upside down on the roof (idea 5). There is a tangential...
relationship between ideas 4 and 5. Idea 4 functions as a springboard towards a whole new direction for generating ideas. The racetrack direction is further explored by idea 17, a train track around the chairs, idea 46, a looping racetrack, and idea 47, a racetrack with airplanes. The link between idea 5 and each of these ideas is of the modification-type. The later ideas are explorations of the search direction opened by idea 5. Finally, designer D develops his 'racetrack with airplanes' idea. Idea 48 is a refinement of the same idea and hence ideas 47 and 48 have a supplementary link relationship. Figure 5.41 shows the link matrix for the these ideas.

![Linking of ideas in brainstorming meeting 1 that lead towards idea 48](image)

Over the duration of almost the entire brainsketching segment, the search direction of the racetrack which was opened up in the first round of generating ideas, is explored and finally developed into the 'racetrack for airplanes' idea.

### 5.6.3 A typical example of the brainstorming linking process

The brainstorming with post-its linking process can be regarded as a continuous pursuit and inspection of new search directions. The typical link matrix consists of brief chains of linking, which are interchanged by moments in which links are mostly made with ideas in the remote sections of the group's external memory. This could be seen as a search for new directions, interspersed with brief explorations of some of these directions. The linking in the brainstorming segment of meeting 2, leading up to idea 52, 'trampoline' provides a typical example of such connections made during brainstorming (see figure 5.25 for the link matrix of this segment). Table 5.11 shows the related ideas.

<table>
<thead>
<tr>
<th>No</th>
<th>I.d.</th>
<th>time</th>
<th>Label (+Notation on post-its)</th>
<th>Subject explanation of Idea</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>H/1</td>
<td>2:02</td>
<td>Ball bath</td>
<td>H: A ball bath</td>
</tr>
<tr>
<td>41</td>
<td>F/12</td>
<td>10:32</td>
<td>Ball bath</td>
<td>F: A ball bath in the car</td>
</tr>
<tr>
<td>46</td>
<td>F/14</td>
<td>11:46</td>
<td>Sandbox</td>
<td>F: A sandbox</td>
</tr>
<tr>
<td>47</td>
<td>H/11</td>
<td>12:00</td>
<td>Seesaw</td>
<td>H: A seesaw</td>
</tr>
<tr>
<td>48</td>
<td>J/11</td>
<td>12:06</td>
<td>Swing</td>
<td>J: A swing</td>
</tr>
<tr>
<td>49</td>
<td>H/12</td>
<td>12:15</td>
<td>Spring-chicken</td>
<td>H: Alright ... a spring-chicken</td>
</tr>
</tbody>
</table>
About halfway through the brainstorming activity, designer F, like most of the other designers in the meeting, is inspecting the earlier ideas for inspiration. (In the general link matrix of meeting, this shows through links made in the remote sections of the matrix, between ideas 35 and 45). He mentions idea 41, which involves installing a ball bath in the car. This idea is a repetition of idea 4, 'ball bath'.

About a minute later, designer F comes up with the idea of a 'sandbox' (idea 46), which he bases on his previous idea of putting a 'ball bath' in the car. The idea of a 'sandbox' opens up a search direction that involves playground equipment, which is explored by ideas 47 to 49. Then, designer G uses the playground concept as a springboard. He generates an idea of including a wave motion in the back seat (idea 50). Designer J, in turn, uses the 'seat with waves' idea as a springboard for his 'trampoline' idea. After these two ideas, the designers again start searching for new directions. Figure 5.42 shows the linkograph for these ideas. Unrelated ideas are omitted in the link matrix.

Instead of the movement from tangential linking to supplementary linking, for brainstorming, the linking is typically characterized by chains of modification links, preceded by either a tangential link that opens up a new search direction, or a supplementary link that re-opens an earlier search direction.
5.6.4 Different purposes of graphic and sentential idea generation techniques

In this second study, we gained the understanding that brain sketching, as a representative of graphic idea generation techniques, and brainstorming with post-its as a representative of sentential idea generation techniques, relate to structurally different idea generation processes. The structure of the brainstorming with post-its process can be regarded as a broad exploration-type problem solving process, which consists of a search for new directions, alternating with brief explorations of some of these directions. The structure of the brain sketching process can be regarded as a design-like problem solving process, which has as typical characteristics, a development from a search for new directions in the beginning of the process, through an exploration of some of these directions, towards incremental development of a few options. The differences in processes suggest that they may serve different purposes in design.

Sentential techniques, such as brainstorming with post-its, may be better suited for serving the traditional role of creativity techniques in design methodology, namely generating a large number and variety of design alternatives. The ideas generated during sentential idea generation consist of short descriptions, which are yet to be developed into design solutions. Within design, there are various more or less structured ways for developing these broad ideas into specific solutions. For instance, the Timbuktu design team - used as an example in Chapter Three (section 3.4)- used brainwriting (Geschka et al., 1973) to generate ideas for the search direction of presents that signify 'protection'. In total, 99 ideas were generated, consisting of brief written descriptions. After the brainwriting technique, the designers developed any interesting idea found among the brainwriting ideas into sketches with more product-like features. For instance, one of the ideas generated by designer F was, 'put ring of sculptures around the house.' After the brainwriting meeting, he returned to that idea, and made the sketch provided in figure 5.43. He explained the sketch in the following way: "I have a ring of little sculptures, but those sculptures are very small, something like this (indicates the size between index finger and thumb) ... and then they are standing in the grass, so you do not see them at all. Except when you walk around, then you find all these little men in the grass."

Sentential idea generation techniques provide many varied, but undeveloped ideas. Including phases of idea development after the sentential technique itself can compensate this lack of development in the ideas.

Graphic techniques, such as brain sketching, provide a more developmental, design-like, idea generation process, and may therefore be better suited when either more idea development is desired, or, when a 'preview' to the design process to come is desired. This, for instance, can be the case in product development, in which kick-off or start-up meetings often incorporate idea generation techniques. One of the objectives for generating ideas during the start-up of a product development team
is to explore the solution area. Another reason is to create a shared understanding within the design team, according to Valkenburg (2000):

*Shared understanding within the design team is the result of harmonizing the individual perceptions of the team members. It is reasonable to assume that shared understanding is a precondition for good team design. In order to synchronize communication and co-ordinate activities team members have to acquire a shared view on the design problem and solution.* (p.26)

Then, an alternative function of using idea generation techniques during kick-off meetings is to provide a quick run-through of the design process that is to come. This simulation allows the designers in the team to gain a shared understanding of the task by discussing the possible directions that came up while generating ideas. Brainsketching may better serve this purpose, as, rather than a broad search, a more directed search that leads to more developed design ideas is desirable.

Notes

1 Based on adaptiveness-innovativeness theory, one would expect a positive correlation between the designer’s KAI score and the tangential link type index, and a negative correlation between the KAI score and the supplementary link type index. However, no such correlations were found.

2 The self-perceived sketching ability correlated negatively with the link density (R=-0.48, p<0.05). Perhaps, participants with good (self-perceived) sketching ability focus more on their current idea sketching process, while participants with a lower (self-perceived) sketching ability more frequently need to visit earlier ideas for inspiration.

3 In the brainsketching segment of meeting 1, one irregularity was found. During the final round of explaining ideas, while designer C is explaining idea 44 'observation turret' idea designer D mentions idea 45, a 'gun turret' game. He then adds an annotation of the 'gun turret' idea to designer C's sketch. The gun turret idea was positioned in the link matrix next to idea 44, because both ideas were generated on the same flip chart, and formally during the same round of generating ideas. In the other three brainsketching segments no such irregularities regarding links within the unlikely link locations were found.
Conclusions and further developments: Sketching in design idea generation meetings

Summarizing conclusions

Introduction

When designers need to generate ideas, they take paper and pencil, and start to produce idea sketches. Or, they may call an idea generation meeting. The available techniques for generating ideas in such idea generation meetings are mainly based on writing as a working medium. This research project started with the notion that idea generation techniques for design could be enhanced if sketching could be included in such idea generation meetings. For, many researchers regard sketching to be instrumental not only to the designer's creative process (e.g. Fish & Scrivener, 1990; Goldschmidt, 1991 Schon & Wiggins, 1992; Goel, 1995) but also to the design team's creative process (Bly, 1988; Tang & Leifer, 1988; Scrivener & Clark, 1994). If we assume that idea generation meetings in design are a specific kind of team design activity, then the attributes of sketching that stimulate design creativity should also be valid for idea generation meetings in design.

The results from the first empirical study introduced complications, which made us divert the search from trying to improve idea generation meetings by including sketching towards gaining a more thorough understanding of the ways in which using sketching rather than writing as a working medium changes the idea generation process. To structure the search, three research questions were composed. The first two research questions related to the two lines of inquiry followed. The third research question dealt with developing a method that allows comparing and investigating the creative processes taking place in idea generation meetings. Based on the results from the two empirical studies (Chapters 4 and 5), we can now reflect on the extent to which we answered these research questions.

This section provides a summary of the answers to the research questions that were found in the empirical studies. In sections 6.2-6.4 additional empirical and theoretical research efforts are reported that help answer the research questions. Then, in section 6.5 we make some further speculations on developing the use of sketching in idea generation meetings. We suggest further development of the brainsketching by putting more emphasis on reflecting on the earlier ideas as a creative group activity. And, some suggestions are provided regarding the applicability of brainsketching for participants who do not have a design background, and therefore may be less comfortable with idea sketching as a working medium. This is especially relevant because many design teams in practice are multi-
disciplinary in nature, which means that at least part of such a team does not have a design background. The thesis is concluded in section 6.6 by suggestions for further research.

6.1.2 Research question 1: How do various ways of including sketching in idea generation meetings influence the idea generation process?

In the creative problem solving literature very few idea generation techniques that use sketching as a working medium were encountered, and we could not detect any empirical investigations of the few graphic techniques found. Only one idea generation technique was uncovered that explicitly incorporates sketching. This technique was referred to as ‘brainsketching’ (VanGundy, 1988).

Brainsketching is entirely non-verbal; participants sketch ideas individually and then exchange sheets to sketch more ideas, using the idea sketches on the paper as a source of inspiration. The brainsketching technique as described in the literature provides a very limited amount of interaction, though it is particularly this interaction between group members which provides the added value of such idea generation meetings in design, especially when working with multi-disciplinary design teams.

In the first empirical study, we wanted to explore whether a more group-oriented idea generation process could be achieved with sketching as a working medium. We developed three direct graphic variations to the brainstorming technique and tried them out in the first study (see section 4.2).

In the design thinking literature, we detected three principal themes regarding the ways in which sketching may contribute to the creative processes of design teams:

1. Sketching supports a re-interpretive cycle in the individual designer’s thinking process; while a designer is sketching he or she is continuously observing and interpreting the consequences of the marks made on the paper.

2. Such re-interpretation can also occur when designers discuss design ideas. Designers can interpret each other’s sketches differently and by doing so open up new directions for further inquiry.

3. Sketches stimulate the use of earlier ideas by enhancing their accessibility.

In order for these functions of sketching to also apply for idea generation meetings, the process of idea sketching needed to be compatible with the process of divergent thinking. This meant that, when compatible, the idea generation process should not degrade when sketching is included, rather, the idea generation process should improve. In Study One (Chapter 4), three variations to the brainstorming technique that included sketching, were applied in experimental meetings. These graphic variations performed substantially less well on parameters that reflected the four
guidelines of divergent thinking, compared to regular brainstorming. This leads to the conclusion that the processes of idea sketching and divergent thinking are not fully compatible.

Because of the encountered incompatibility, we could not verify whether the three purported theoretical functions of sketching for design groups were also applicable for idea generation groups. In Study Two (Chapter 5) we gained further understanding regarding the different characteristics of the graphic and the sentential idea generation process. By re-interpreting the data from this second empirical study we can now revisit these functions (a detailed description of this study is provided in section 6.2). The results of this additional study show that there is some evidence in support of the first function, sketching stimulating a re-interpretive cycle for the individual designers. Also some support was found for the third function, the increased use of earlier ideas because of the enhanced accessibility. No support was found for the second function, which suggested that the group members re-interpret each other’s ideas through sketching.

Research question 2: What are the differences in the structure of idea generation processes, when sketching or written language is used as a working medium?

Upon detecting incompatibility between the activities of idea sketching and brainstorming in the first empirical study, the search was redirected towards achieving a more thorough understanding of the nature of the differences in structure of the idea generation processes, when sketching or writing is used as a working medium. In the second empirical study we compared the processes of two techniques that were considered to represent the working media of writing and sketching. Brainstorming with post-its (Isaksen et al, 1994) was found to be an appropriate representative of sentential idea generation techniques. A variation to the brainsketching technique (VanGundy, 1988) was developed to provide an appropriate representative of graphic idea generation techniques. The version of brainsketching reported by VanGundy was entirely non-verbal. Participants sketch their ideas individually on large sheets of paper pasted on the wall. After a few minutes, the participants switch places and continue sketching, while using the ideas drawn on the sheets by other group members as a source of inspiration. Usually about five such rounds take place. To provide an appropriate representative of graphic group idea generation, a more group-oriented technique was required. In the variation to brainsketching that we developed, which we referred to as ‘interactive brainsketching’, participants briefly present their ideas to each other in between rounds of idea sketching. A small pilot showed that compared to ‘regular’ brainsketching, the participants were found to make substantially more connections with each other’s ideas when using interactive brainsketching.
The two representative techniques were compared in the experimental meetings. The representative techniques are quite different in nature. During brainstorming with post-its, the designers generate ideas in the group, while during brainsketching, designers generate ideas individually in rounds, and after each round they share their ideas in the group. As a consequence, more than just the effects of the different working media were compared in the study. A 'cleaner' empirical study would have been achieved if we had been able to compare a graphic and a sentential variation to a single idea generation technique. However, both working media appeared to require different ways of working. For instance, the graphic variation to brainstorming with post-its, which we called 'visual brainstorming', was found to deteriorate the idea generation process substantially in the first empirical study. And the written alternative to brainsketching, called brainwriting (Geschka et al, 1973) was also found to be sub-optimal.

What, then, were the differences found? The sentential idea generation process -of which brainstorming with post-its was a representative technique- was found to involve a broad search for new directions supplemented by brief explorations of some of these directions. Hardly any idea refinement takes place. Figure 6.1 shows a simplified view of the sentential idea generation process. This is in line with what one would expect when considering the guidelines for divergent thinking.

The graphic idea generation process was found to include more integration of the earlier ideas and more idea development and refinement, while maintaining a ratio of new search directions that is similar to the brainstorming with post-its technique. Graphic idea generation techniques can be considered to represent a design-like problem solving process, which is signified by a search for various novel directions in the early phases of the process, followed by an exploration of some of these directions, and an emphasis on incremental development of ideas in the final phase. Figure 6.2 shows a simplified view of the graphic idea generation process.

The different characteristics of the graphic and sentential processes suggest that they may serve different purposes as design methods. Sentential idea generation may better serve the traditional role of creative problem solving techniques in design methodology, which is to generate a large number and variety of design ideas, of which some can be selected to further develop into design solutions. Graphic techniques may be more suitable when, instead of a large number of ideas, a smaller but more refined collection of novel design ideas are desired. For instance, graphic techniques can be applied in a design project start-up meeting to provide a quick simulation of the design process to come. Such a simulation allows the designers in a team to gain a shared understanding of the design task by discussing possible pathways towards solutions that came up when generating ideas.

So, based on the empirical data, we have found differences in structure and we suggested differences in application of the graphic and sentential idea generation processes. How then can these differences be explained on a theoretical level?
And, as the existing guidelines for divergent thinking are instrumental to sentential idea generation, can we develop an alternative set of guidelines to support the different structure and applicability of the graphic idea generation process? These questions are addressed in section 6.3.

Research question 3: How can idea generation processes be described in such a way that differences in these processes can be analyzed, in order to answer the questions regarding the role of sketching in idea generation meetings?

Linkography has been further developed and applied to analyze the data of two experimental studies. Here we will evaluate the adaptations made to Goldschmidt's original approach and we will review whether the method has proved to be an appropriate approach for analyzing the processes in idea generation meetings.

First of all, we need to re-assess the extent to which the adaptation to linkography made indeed overcame the two criticisms regarding the original linkography method made in design thinking research. To recap: 1) The method relying on sub-dividing protocols into 'design moves' was regarded to be open to interpretation; 2) The method relying on 'common sense' in deciding whether or not there is a link between two design moves was considered too subjective (see section 3.3).

The first issue was dealt with by selecting protocol fragments that related to design ideas, rather than design moves, from the idea generation meeting protocols. Analyzing idea generation meetings -instead of the more common form of experimental meetings which is unguided group design work- had the advantage that a relatively clear working definition could be provided. In order to be accepted a 'design idea' had to be communicated. A verbal remark had to be made and there had to be a representation of the idea on the flipcharts. And, an idea had to be related to the task at hand, providing some kind of a solution or a direction for further search. This working definition of design ideas, at least, was less open to interpretation as it did not rely on making decisions about changes in the relative state of the design.

The second issue, determining links between design moves based on similarities in subject matter, is especially relevant when investigating the links between ideas. Ideas may build on each other, while they relate to entirely different subject matter. Often, the source idea is used as a 'springboard' for the later idea (e.g. Nolan, 1987). This issue has been dealt with in the two empirical studies by providing guidelines for linking that emphasize situational -or context- indicators for linking such as, designers referring to earlier ideas when explaining the current idea, or pointing at a previous idea when explaining the current idea (see section 3.4).

One additional question will be addressed later in this chapter to help further understand the role of context indicators when determining links between ideas:
What is the nature of the context indicators, and how important are they? Perhaps, links could be determined solely by means of such context indicators. If this were possible, it would provide a more objective scoring method. In section 6.4 the context indicators found within the videotapes of two of the experimental meetings in the second study are analyzed. This results in nine categories of context indicators and an indication of their relative importance for the graphic- and the sentential idea generation technique. The results also show that between 59% and 83% of the 'certain' links -which both the researcher and the independent judge marked as a link- were supported by strong context indicators. This means that context indicators are an important factor to take into account when determining links, but they are not sufficient.

Applying linkography to compare the processes of idea generation meetings imposed three additional criteria. First, the graphic display used needed to be accessible. The display needed to provide a neutral overview of the linking process and it needed to be easily understood by other researchers. Secondly, the linking display needed to be flexible. We used the linking display for many analyses, such as determining the link density, self-linking and link type indices, but also to determine the inter-rater agreement. The linking display used needed to be flexible enough to allow for performing these various kinds of analyses. Finally, the linkography approach used needed to provide results that could be compared between meetings. We adapted and modified the linkography method to meet these criteria.

In comparison to the original version of linkography, we changed the appearance to meet the accessibility and flexibility criteria. Figure 6.4 shows a linkograph provided as an example by Goldschmidt (1996) next to our version of a linkograph with a similar number of moves or ideas.

We used a matrix format in Microsoft Excel to produce linkographs. Apart from the benefit of being able to use an existing application, the matrix format also allowed for easy operations and calculation of link indicators. And, in research, the matrix
format is commonly used (e.g. a correlation matrix). The disadvantage of the matrix format is that it is less accessible for graphic interpretation of the process. Goldschmidt specifically developed the linkograph to facilitate graphic interpretation of the design process. We used the linkographs mainly as an intermediary stage for assessing the links between ideas, after which the various link indicators were calculated. Because of the lines connecting the link nodes, links between ideas are much more graphically emphasized in Goldschmidt’s linkographs. Because of that, patterns in the linking behavior of the designer(s) are more easily recognized.

We did not make a lot of use of the linkographs themselves for comparing the various experimental meetings. Instead, we used the indicators because they allowed for objective comparison between the meetings, thus meeting the comparability criterion. We used and, when necessary, developed, the following indicators for linking:

- The **number of ideas** generated has been used as a dependent variable, even though this is not an indicator for linking, because it is a direct indicator of the extent to which the ‘striving for quantity’ guideline is met.

- The **link density** is an indicator of the degree of integratedness of the process. A high link density indicates that ideas have many connections with earlier ideas. Therefore, the link density is an indicator for the extent to which the participants build on earlier ideas. Goldschmidt used the same variable in her research, which she referred to as the ‘link index’. As this variable indicates the number of links per idea, we used the term link density as a more accurate term.

- The **self-link index** is the ratio of links that the designers make with their own earlier ideas, divided by their total number of links made. Together with the link density, the self-link index indicates to what extent the ‘building on each other’s ideas’ guideline is met. For a group size of four designers, a self-link index under 0.25 indicates a ‘full’ group process (see Section 3.5).

- The **link-type indices** (Supplementary, Modification, Tangential) indicate the nature of the connections made. After the general link matrix was produced for a meeting, for each link the nature of the connection was assessed. Tangential links indicate wild leaps in a different direction, Modification links indicate direct variations and Supplementary links indicate small alterations. The link type indices have been an important instrument for determining the differences between the graphic and the sentential idea generation processes. Unfortunately, the inter-rater agreement was found to be insufficient for the link type indices. Even though there is an obvious explanation for this\(^1\), the lack of inter-rater agreement detracts from the confidence level of the results. A better-defined set of instructions for determining the link types in a link matrix may help overcome this problem.

In addition to these general indicators, in Chapter 5 we introduced an additional link indicator that specifically addressed the different interactions with notations
made in 'external memory'. Four categories of links were defined, which
differentiated between immediate -or direct- and more distant -or remote- links
made, and between individual and interpersonal links made with ideas in external
memory. This indicator showed the link density for each of the four types of links
with ideas in the group's external memory.

For the brainsketching technique, a clear distinction could be made between
direct and remote linking. All links made with ideas in the current and the previous
round of generating ideas -which were shared just before the designers started
generating ideas in the current round- were included in the direct linking area. It
was less clear-cut to make this distinction for the brainstorming with post-its
 technique. We assumed that a bandwidth of ten ideas provided an appropriate direct
linking area. Every link with ideas that were generated before the ten previous ideas
was regarded to be a remote link. The theoretical support for assuming this ten-
ideas bandwidth is light. As the direct part of external memory is regarded to extend
short-term memory (Newell & Simon, 1972), and as the short-term memory is said
to contain seven plus or minus two chunks, choosing a bandwidth of ten ideas
appeared reasonable, because it reflected a small extension to short-term memory.
Inspecting the link matrices in this thesis shows that, indeed, there appears to be
an area of higher density of links along the diagonal, which is covered by the ten-
idea bandwidth.

The link densities for the four categories of interactions with external memory
helped to provide some insights into similarities and differences between the
graphic and the sentential idea generation process, but it was especially useful for
isolating the various theoretical functions of sketching in design meetings (see
section 6.2).

The use of these overall indicators for the qualities of the linking in the matrices
allowed for a relatively quantitative comparison of the various conditions. And, it
allowed for combining the results of the various meetings. However, the general
approach does not identify specific occurrences within parts of the meetings. This
limitation was especially felt when exploring whether the individual function of
sketching stimulated a re-interpretive cycle as reported in theory. We could identify
certain prerequisites for this function, but the cyclical movement itself could not be
identified (see section 6.2). More than a limitation to the linkography approach,
this is a limitation to the experimental design used. For, even if we had examined
the link matrices for specific linking patterns, the type of data available did not
allow inspection of the reasoning patterns used by the designers themselves while
generating ideas. While brainsketching, designers generate ideas individually. To
examine whether an individual re-interpretive cycle is taking place, we would have
needed to, for instance, have asked the designers to think aloud whilst generating
ideas. For practical reasons (it is rather complicated to record five designers
thinking aloud while they are generating ideas in parallel) we kept to making
videotapes of the group process. Additional experimental meetings that are specifically designed to uncover the individual thinking processes could be used to investigate the presence of such an individual idea generation cycle.

Using linkography for assessing the processes of idea generation techniques provided a valuable alternative to the currently predominant 'outcomes' approach. The linkography approach is fairly laborious, but it provides many more insights into the ways in which these techniques work. Linkography is a research method in development. Before it can be seen as a mature research method, some of the issues raised above need to be dealt with. In section 6.6, suggestions for further research are provided, to help deal with these issues.

How including sketching in idea generation meetings affects the idea generation process

6.2 Introduction

Both sketching and idea generation meetings are regarded as stimulating the creativity of product design groups. This research project was initially guided by the assumption that superposition of these two 'tools' for stimulating creativity would provide an even stronger tool. In Chapter 2, potential functions of sketching in idea generation groups were identified. However, the results from the first empirical study in this project suggest that the assumption was incorrect. The idea sketching process appears to be structurally different from the brainstorming process, which means that combination of the two tools does not automatically lead to a conjunction of their assets. Therefore the second empirical study focused on gaining an understanding of the differences between sketching and writing as working media in idea generation meetings. With these differences in mind, we can now revisit the functions found in design theory, and evaluate their relevance in the context of idea generation meetings. The three basic functions of sketching in design activity that could have a role in idea generation meetings were (see section 2.4):

1. The thinking sketch (relating to interaction with the individual-direct part of external memory) stimulates the designer's creativity by supporting a re-interpretive cycle.
2. The talking sketch (relating to interaction with the shared-direct part of external memory) stimulates creativity in design groups by inviting re-interpretation.
3. The storing sketch (relating to interaction with the remote parts of external memory) provides a more integrated idea generation process by enhancing the accessibility of earlier ideas.

In figure 6.4 these basic functions are located in the model of the designer's interactions with information in the group's external memory (see section 5.4).
The link matrices from the second empirical study may provide insights in their applicability to idea generation meetings in design. However, the evidence that can be acquired through linkography is limited, as the link matrices and link indices do not always provide the fine-grained view of the process required to, for instance, identify cyclical patterns of idea generation (this limitation will be further discussed in section 6.6). However, some general indications can be provided, at least to inspect whether there is evidence against the potential functions of sketching in idea generation meetings as found in Chapter 2.

6.2.2 Function 1: Sketching supports an individual re-interpretive cycle.

In Chapter 5, we already observed that individual idea generation has a substantial role in the graphic idea generation process. Compared to brainstorming, ideas had significantly more connections with ideas in the individual-direct area of the external memory (see figure 6.5).

This does not provide proof of a cyclical movement, but at least it shows that there is a substantial interaction between the designers and the individual-direct parts of their external memory, which is a prerequisite to such an idea generation cycle.

To identify whether a re-interpretive cycle is taking place, we would have to be able to analyze the reasoning taking place connected to the marks made on the paper. In experimental meetings in design research, designers are often asked to 'think aloud' as a means for the researchers to get insights into the cognitive processes taking place (see Lloyd, Lawson, & Scott, 1996, for a critical discussion of this research approach). In the studying of group processes, the verbal remarks made can be regarded to provide insights into the reasoning of the designers. Even though brainsketching is a group method, the actual idea sketching itself is an individual activity. For practical reasons, we did not ask the designers to 'think aloud' while they were involved in idea sketching. Therefore, the primary data available -the videotapes and flipcharts- are not suitable for analyzing whether a re-interpretive cycle is taking place while the designers generate ideas (in section 6.6 we suggest further research to deal with this issue).
The purported function of sketching in idea generation groups is that the re-interpretation taking place in an individual idea sketching cycle is said to be conducive to creativity. Purcell & Gero (1998) describe such re-interpretation as: "the emergence of new ways of seeing the perceptual (drawn) representation of a potential design" (p. 396). Suwa & Tversky (1997) relate re-interpretation to "... acts of shifting the focus of attention" (p. 394). For idea generation meetings, such 'new ways of seeing' or 'focus shifts', can contribute to the creative process by opening up new directions for further exploration. The level of tangential linking can be seen as an indicator for such creative re-interpretation taking place. Tangential links indicate possible focus shifts, which may be further explored through direct association, identified by modification linking, and steps of incremental development, identified by supplementary linking.

So, a relatively high ratio of tangential links can be seen as a basic indicator that the working medium used supports creativity through re-interpretation. The comparison of the overall link type indices in Chapter 5 did not show a substantial difference in tangential-type links. For the brainsketching segments, the mean tangential link type index was even slightly lower (LTI_T =0.31, SD=0.15) than for brainstorming (LTI_T = 0.36, SD=0.17). The absence of a significantly higher tangential link type index for the brainsketching condition indicates that the graphic condition did not stimulate creativity by providing a significantly higher ratio of novel connections.

By comparing the link type indices for the area of external memory at hand -the individual direct area- with the overall link type indices, we can evaluate the relative contribution to the creative process of the proposed individual re-interpretive cycle. The link type indices for the links with ideas in the individual-direct area provide a rough indication for the nature of this part of the process.

In Chapter 5, the main analysis was on the level of the individual designers. However, sub-dividing the links, first into the four areas of external memory, and then into the three link types for each designer results in too few links per condition to provide dependable results. Therefore, we reverted to the group level of analysis for determining the link type indices for the various areas of external memory, for the four brainsketching- and four brainstorming segments.

When investigating whether including sketching supports a creative cycle of re-interpretation, the link type indices for the linking with the individual direct area is most relevant. Figure 6.6 provides a graphic display of the mean link type indicators, for the individual direct area and the total link matrix.
Compared to the mean score for the links in the link matrix (see section 5.5), in the individual direct area of the brainsketching segments, a relatively high ratio of tangential linking takes place (LTI_t = 0.50, SD=0.04), compared to the overall tangential link type index (LTI_t = 0.32, SD=0.15). The supplementary link type index is lower, but not substantially so (Individual Direct: LTI_s = 0.19, SD=0.04; Overall: LTI_s = 0.25, SD=0.15). Compared to the average, relatively little modification linking takes place in the individual direct area (Individual Direct: LTI_M = 0.32, SD=0.08; Overall: LTI_M = 0.44, SD=0.15). The high ratio of tangential links indicates that in the individual direct area of external memory a high ratio of wild leap-type connections is made with earlier ideas. This indicates that the linking in the individual direct area stimulates creativity by opening novel directions.

### 6.2.3 Function 2: Sketching invites re-interpretation of each other’s ideas.

Similarly to the previous individual direct function of sketching, the link type indices for the shared-direct area provide some insight into the nature of the connections made with the recently generated ideas of other designers. In chapter 5, we noticed that for both brainstorming and brainsketching the shared direct area is an important source for making connections (see figure 6.7).

As in the previously mentioned function of sketches for the individual design process, if sketches stimulate creativity through inviting re-interpretation of each other’s sketches, this should show by a relatively high ratio of tangential links and
a relatively low ratio of supplementary links for the brainsketching condition, compared to the average link type indices for brainsketching (see figure 6.8).

![Figure 6.8: Mean link type indices in the graphic condition for the links in the shared-direct area compared to the overall link type indices for the graphic condition.](image)

This comparison does not provide any strong differences between the overall link type indices, and the link type indices for the shared-direct area. There is no notable difference in the tangential link type index (Shared direct: LTI_T = 0.29, SD=0.06; Overall: LTI_T =0.32, SD=0.15). The modification-type link index appears to be somewhat higher (Shared direct: LTI_M = 0.51, SD=0.05; Overall: LTI_M =0.44, SD=0.15), and the supplementary link type index appears to be somewhat lower (Shared direct: LTI_S = 0.20, SD=0.09; Overall: LTI_S =0.25, SD=0.15). This is not in line with what one would expect if the creative process were influenced by the proposed function of the designers re-interpreting each other’s idea sketches.

Re-interpretation of each other’s ideas may not only occur in the shared-direct area, but also with ideas that stem from the shared-remote area, because these ideas need to be accessed through the shared-direct area of external memory. Therefore it is relevant to also inspect the link types for this part of external memory (see figure 6.9).

![Figure 6.9: Mean link type indices in the graphic condition for the links in the shared-remote area compared to the overall link type indices for the graphic condition.](image)

For the supplementary and the modification link type index, the standard deviations are too large to make any sensible inferences regarding the differences in means between the shared-remote and the overall link type index (Shared remote: LTI_S = 0.27, SD=0.17; Overall: LTI_S = 0.25, SD=0.15; Shared remote: LTI_M=0.48, SD=0.13;
Overall: $\text{LTI}_{\text{m}}=0.44$, $\text{SD}=0.15$. The tangential link type index inclines towards being lower than average (Shared remote: $\text{LTI}=0.25$, $\text{SD}=0.03$; Overall: $\text{LTI}=0.32$, $\text{SD}=0.15$) which, again, invalidates the notion that including sketching in idea generation meetings stimulates re-interpretation in each other’s sketches.

6.2.4 Function 3: Sketching enhances the accessibility of earlier ideas.
Because sketches may be easier to identify in the external memory, the designers are more likely to make use of the ideas in the remote area of external memory, which consists of the individual remote area and the shared remote area. Comparing the link densities in these areas of external memory for the graphic and for the sentential condition provides a basic indication of whether this function of sketching is relevant for idea generation meetings (see figure 6.10).

As mentioned in Chapter 5, designers make few connections with ideas in the individual remote area of external memory in both conditions. And, there is no substantial difference between the link densities for the individual-remote area (for the graphic condition: $\bar{X}=0.13$, $\text{SD}=0.12$; for the sentential condition: $\bar{X}=0.09$, $\text{SD}=0.09$). Many more connections are made with the shared remote area. Here, there is a significant difference between the link densities. The mean link density in the shared-remote area for the graphic condition ($\bar{X}=0.35$, $\text{SD}=0.22$) is significantly ($p<0.05$) higher in comparison to the sentential condition ($\bar{X}=0.20$, $\text{SD}=0.18$). Thus, in the sketching condition, ideas have many more connections with ideas in the shared remote part of external memory. The link indices do not make it exactly clear, whether this higher amount of linking can be attributed completely to the improved accessibility of sketches in the shared remote area of external memory, but at least it does not invalidate the function. As for the proposed individual function, other types of data analysis are required to provide more definite answers regarding this matter.

6.2.5 Functions of sketching in idea generation meetings
Of the three proposed functions of sketching in design groups, no evidence was found in support of the second one, which states that sketches stimulate creativity by inviting re-interpretation of each other’s idea sketches. It appears that sketches
stimulate creativity in idea generation groups, especially in the immediate 
individual idea generation process. And, sketches may provide a more integrated 
group process, by providing better access to the earlier ideas (see figure 6.11).

The first individual aspect of sketching particularly accounts for why the ‘visual 
brainstorming’ technique failed in the first empirical study (see Chapter 4). Visual 
brainstorming was a direct variation to brainstorming with post-its. Designers were 
asked to sketch ideas on individual sheets of paper and, when done with a sketch, 
immediately share the idea with the group, whereupon the facilitator pasted the 
sheet with the idea sketch onto the flipchart. This technique does not allow for the 
individual idea generation cycle, in which new search directions can be found. 
Indeed, the technique not only lacked quantity of ideas (only 17 ideas were 
generated, compared to 46 for the control condition, in which regular brainstorming 
was applied), but the tangential link index was also especially low for visual 
brainstorming \((LTI_v=0.21, \text{ compared to } LTI_r=0.46 \text{ for regular brainstorming})\), 
indicating few new connections that could open up novel directions for generating 
ideas.

**Differences in structure of the sentential and graphic idea generation processes**

In the second empirical study (Chapter 5), we gained the understanding that 
brainsketching as a representative of graphic idea generation techniques, and 
brainstorming with post-its as a representative of sentential idea generation 
techniques, relate to structurally different idea generation processes. The structure 
of the brainstorming with post-its process can be regarded as a broad exploration- 
type problem solving process, which consists of a search for new directions, 
terspersed with brief explorations of some of these directions. The structure of the 
brainsketching process can be regarded as a design-like problem solving process, 
which has as typical characteristics, a development from a search for new directions 
in the beginning of the process, through an exploration of some of these directions.
towards incremental development of a few options. The differences in processes suggest that they may serve different purposes in design.

Sentential techniques, like brainstorming with post-its, appear to be better suited for serving the traditional role of creativity techniques in design methodology, namely generating a large amount and variety of design alternatives. The ideas generated during sentential idea generation consist of short descriptions, which are yet to be developed into design solutions.

Compared to sentential techniques, graphic techniques, such as brainsketching provide a more integrated and developmental idea generation process, while maintaining a similar level of novel connections made. Graphic techniques therefore appear to be better suited when either more idea development is desired, or, to provide a quick run-through of the design process that is to come. This simulation allows the designers in the team to gain a shared understanding of the task by discussing the possible directions that came up while generating ideas.

We will further investigate the structural differences between graphic and sentential idea generation by relating them to theory, and then we will reconsider the appropriateness of the four guidelines for divergent thinking, concluding by proposing an alternative set of guidelines for the graphic idea generation process.

### 6.3.1 Differences in activities in graphic and sentential idea generation

Here we will examine the theoretical differences in the basic activities that take place in graphic and sentential idea generation meetings. A representation of the current view on the activities in the creative problem solving stage of idea-finding is provided in figure 6.12. The stage consists of a divergent phase that focuses on idea production and a convergent phase of idea evaluation. According to Osborn (1963), the divergent phase is intended to gather a 'checklist' of ideas, from which one can select ideas in the adjacent convergent phase.

An alternative view is provided by Finke, Ward, & Smith (1992), who propose, what they call, a 'heuristic model of creativity' called 'Geneplor' (see figure 6.13) in their efforts to develop a creative cognition approach to understanding creativity. 'Geneplor' is a combination of the verbs 'generate' and 'explore'. Finke et al argue that creative cognition involves a repeating cycle that contains a generative phase in which so-called pre-inventive structures are constructed, and an exploratory phase, in which the generated pre-inventive structures are interpreted. The results of these interpretations lead to insights that can be used to either focus on specific issues, or to expand conceptually, by modifying the pre-inventive structures. In the model, product constraints can be imposed at any time during the generative or exploratory phase.

The pre-inventive structures are central in Finke et al's theory. They observe:
These (pre-inventive) structures can be thought of as internal precursors to the final, externalized products of a creative act. They can be generated with a particular goal in mind or simply as a vehicle of open-ended discovery. They can be complex and conceptually focused or simple and relatively ambiguous, depending on the situation and the requirement of the task. (Ward, Smith, & Finke, 1999, p. 192)

According to Ward et al (1999), both idea sketches and words -or, as they call them, ‘verbal combinations’- can represent such pre-inventive structures. With the Geneplore model in mind, we can now start to infer differences in activities for the graphic and the sentential conditions. In figure 6.14 the two phases of the Geneplore model are included in the idea-finding stage.

The depictive characteristics of sketches provide a rich basis for interpretation by allowing the designers to envision the consequences of the ideas. Fish & Scrivener (1990) consider that: “The necessity to sketch arises from the need to foresee the results of the synthesis or manipulations of objects without actually executing such operations” (p. 117). Written language, which is descriptive in nature, refers to classes of objects rather than specific objects, which does not allow the designers to envision the consequences of the specific ideas. This stimulates the generation of ideas by allowing the designers to make free associations, but the inability to envision the consequences of the generated ideas, makes writing as a working medium less supportive of the interpret phase in the Geneplore cycle.

This corresponds with the findings in Chapter 5, which show that during brainstorming, significantly more ideas are generated, and significantly fewer connections with earlier ideas are made. Conceivably, there is little place for interpreting ideas during brainstorming. Participants do build on each other’s ideas -this is supported by one of the guidelines- but the nature of such connections made can be regarded to be mostly concerned with brief inspections that spur further associations, rather than more detailed interpretation of the ideas. The guidelines for divergent thinking stimulate this, by dismissing any type of judgment from the divergent phase. According to the creative problem solving method, interpretation is regarded to be a kind of judgment, as interpretation involves assessing the consequences of the idea for the further generation of ideas.

The graphic idea generation process appears more closely connected to the generate-interpret cycle. In design research, various idea-sketching cycles have been proposed, which suggest that designers reflect on what they are sketching, while they are sketching it. For instance, Goldschmidt (1990) refers to design sketching activity as a ‘dialectic of sketching’, and in her research she showed how designers switch between making graphic propositions, followed by language-like interpretations of these graphic propositions (see Chapter 2). Schön and Wiggins (1992) considered the designer to be involved in a ‘reflective conversation’ with the
drawing surface, meaning that the designer interprets the consequences of a drawing act while he or she is making the mark. Other models of the idea sketching process propose a larger cycle. For instance, Zeisel (1981) proposes a cycle of imagine-present-test, which involves imagining (part of) a design solution, followed by externalizing this solution by means of, for instance, a sketch, followed by evaluating the sketch, which in turn leads to further imagining to deal with the consequences of this 'test'-phase. Reflecting on these previous theories, a basic model of idea generation through sketching can be considered to consist of two basic steps between which the designer shifts continuously. One step is related to producing (part of) a sketch of an idea on the paper and the other step consists of exploring and interpreting the sketch made in order to find directions for further idea sketching. In the previous section we found some evidence for such re-interpretation taking place in the individual designer’s idea generation processes, even though the primary data sources did not allow for verifying the presence of a cyclical movement (see section 6.2).

6.3.2 Reconsidering the divergent thinking guidelines when sketching is used
With the notion of the different area of application, and with the different activities in mind, we can now reconsider the appropriateness of Osborn’s (1953) guidelines for divergent thinking (‘defer judgment’, ‘strive for quantity’, ‘freewheel’, and, ‘build on other ideas’) when sketching is concerned. And, we can develop a new set of guidelines for divergent thinking that accommodates the qualities of the graphic idea generation process.

**Deferring judgment**
Osborn (1953) and other Creative Problem Solving authors (e.g. Isaksen et al, 1994) use the words judgment, criticism, analysis, reflection, and evaluation interchangeably. The guideline suggests postponing the use of these kinds of analytical thinking towards the convergent phase. The main purpose of divergent thinking is, in Osborn’s words, to "create a checklist of possible leads to solution" (Osborn, 1963, p.124), which can be inspected upon completion. There is no interpretation of earlier ideas when using brainstorming, beyond using earlier ideas as a springboard for further association.

We have noticed that total deferment of judgment does not appear possible, and is not desired, when engaged in idea sketching. The creative potential of sketching appears to be located in the interpretation phase of the Geneplore model (Finke et al, 1992). Dismissing this phase through enforcing the deferred judgment guideline is bound to deteriorate the idea sketching process. Besides that, it does not appear possible for the designers to avoid interpreting their sketches while producing them (see section 4.5), which means that the designers cannot conform to the deferment of judgment rule, even if they want to.
Rather than dismissing any judgment in the divergent phase, for graphic idea generation techniques, efforts should be directed towards the participants engaging in an inquisitive type of reflection or interpretation of idea sketches. For banning judgment entirely does not appear to be possible, see the ‘visual brainstorming’ example in Study 1. Analytical thinking within the divergent phase should be directed at finding new clues or directions for further idea generation, rather than being directed towards judging the quality of the idea at hand. According to Finke et al., ‘pre-inventive exploration and interpretation’ leads to further idea generation that either focuses or expands the concept. Focusing the concept consists of refining the idea. Expanding the concept refers to redirecting the search based on the recently gained knowledge. The evaluation of ideas should then still be located in separate convergent phases within the creative problem solving model.

The ‘striving for quantity’ guideline also needs to be reconsidered. Fluency of idea generation is a relevant process characteristic for both sentential and graphic techniques. However, the underlying objective is different. In brainstorming, the main motive for asking for a large quantity of ideas is based on an almost statistical type of argument that the large quantity of ideas is bound to include more high quality ideas. Indeed, for the brainstorming technique a high correlation between quantity and quality of ideas was found by various researchers (e.g. Christenson, Guilford, & Wilson, 1957; Hocevar, 1979; Stroebe & Diehl, 1994). Some researchers even state that, because of the high correlation between idea quality and the quantity of ideas generated, the quantity of ideas generated is the only relevant dependant variable to be used when investigating the effectiveness of brainstorming groups (e.g. Hocevar, 1979).

For brainsketching, however, the constructive reflection within the idea sketching cycle makes for a more directed approach to generating ideas, so that a high quantity of ideas does not necessarily imply a higher quality of ideas. It is more likely that the effectiveness of the reflective cycle strongly influences the quality of the generated ideas. This effectiveness is -in addition to the quality of the generative and the reflective phases- related to the swiftness in which cycles take place. A high number of cycles contribute to the idea sketching process by allowing for many opportunities for redirecting the process. Another reason for promoting fluency in the idea sketching process is to avoid over-development of specific ideas. When idea sketching, some participants may be inclined to produce advanced drawings of ideas, rather than quick and messy sketches. Such advanced drawings are likely to induce early crystallization (see Goel, 1995) and are therefore undesirable in idea generation through sketching. Furthermore, a high fluency of generating ideas prevents participants from lingering in the interpretive phase, thereby encouraging constructive interpretation, rather than critical evaluation. Instead of the quantity of ideas generated, the swiftness of the idea generation
process is important when idea sketching. This suggests a more process-oriented guideline of ‘ideational fluency’.

Building on each other’s ideas The results from the experimental studies in this project suggest that ‘building on each other’s ideas’ is an important guiding principle when using sketching in idea generation. For brainstorming, this guideline relates to using earlier ideas as a mere springboard for spurring the generation of more ideas. In the graphic idea generation process, the building on each other’s ideas guideline is especially relevant. The primary objective for inviting designers to make connections is to incorporate information from ideas that were generated earlier on, into the current idea generation process. Building on other ideas stimulates a well-integrated idea generation process (see section 3.2).

Freewheeling Finally, the freewheeling guideline, which stimulates the participants to express their wilder ideas, is especially relevant for the brainsketching situation. It is an additional means of avoiding early crystallization. As mentioned before, sketching tends to direct the idea generation process towards idea development, even when this is not yet desired. The freewheeling guideline assists the participants in opening up new directions for generating ideas, by stimulating the participants to generate wild or seemingly irrelevant ideas, which can then be interpreted towards more feasible ideas.

The analysis of the data from the second study in section 6.3 indicates that, while brainsketching, especially connections made with one’s own ideas open up novel directions through wild leap-type connections. Freewheeling appears most relevant for the individual interpretive idea generation cycle.

6.3.3 Four alternative guidelines for graphic idea generation techniques
The appraisal of the appropriateness of Oborn’s four divergent thinking guidelines leads to suggesting the following four alternative divergent thinking guidelines for stimulating the idea generation process when sketching is involved:

Build on each other’s ideas. Inspect each other’s ideas for information that can be useful for integrating into new ideas.

Interpret ideas constructively. Interpret ideas by seeking suggestions or directions for further idea generation, rather than assessing and estimating the value of the idea as an artifact. This guideline stimulates a directed search into novel directions.

Strive for ideational fluency. Stay away from over-developing or keeping interpreting sketches of single ideas. Try to accomplish a flow of idea generation, in
which you swiftly alternate producing ideas and interpreting them to gather clues for further idea generation.

**Look for wild connections, especially when interpreting your own ideas.** Make sure that you share and interpret your wildest ideas, because they can lead towards interesting novel directions.

This is a first attempt at providing alternative guidelines for divergent thinking when sketching is involved, and they can be further developed and evaluated by means of further research. These guidelines are based on the assumption made that being well-integrated corresponds with quality of the idea generation process. We attempted to reason why this applies (see section 3.2), but as long as we cannot back this assumption up with empirical evidence, the dependability of the inferences made is limited. This is acceptable, because of the exploratory nature of this research project, but if we want to take the alternative set of guidelines further, we need to provide more definite conclusions regarding the relationship between being well-integrated and quality of the idea generation process.

Techniques for generating ideas that use sketching as a working medium can be further developed, to better comply with these alternative guidelines. Later in this chapter we will, among other things, provide suggestions for developing the brainsketching technique (section 6.5), and recommendations for further research (section 6.6).

**The role of context indicators in linkography 6.4**

**Introduction 6.4.1**

During linkography, for each idea, links with earlier ideas are determined by means of gathering and evaluating evidence of connections. Evidence can be found within the content of the ideas, which are referred to as ‘content indicators’. Situational evidence, which is not part of the content of the ideas, are referred to as ‘context indicators’. Context indicators can consist of, amongst others, gestures or remarks made by the designers when they explain their ideas, physical action when conceiving of the idea, or connecting symbols on the flipcharts. Making explicit use of these context indicators while constructing link systems may enhance the reliability of linkography as a method for data analysis. As generating ideas is a process that, at least partly, occurs within the minds of the designers, there are bound to be occasions where no context evidence for linking can be found, while the content of the ideas strongly points towards a connection between the two. This means that subjective judgement, based on Goldschmidt’s (1996) notion of ‘common sense’, will remain to play a role in linkography, albeit a smaller one.
The link in the brainsketching segment of meeting 1 in the second study, between the previously discussed idea 45, 'gun turret', and idea 44, 'seat rises into see-through turret' (see figure 6.15) provide an example of a link between ideas backed up by both content and context indicators. The content indicator consists of the strong likeness of the ideas. By simply adding toy guns to idea 44 the observation turret transforms into a gun turret. In addition to the content indicator, there are three strong context indicators: First, designer D shouts 'Yes!' in reaction to the see-through turret idea, and then directly starts explaining his idea. Second, designer D points at idea 44 and mentions: 'that one (points at idea 44) combined with that one (points at idea 35; 'virtually shooting other road users'). Third, idea 45 is positioned very closely to idea 44. In fact, idea 45 merely provides an annotation to idea 44. Together this is more than enough evidence for accepting a link between ideas 44 and 45.

![Figure 6.15: Brainsketching segment in meeting 1 idea 44: Seat rises into see-through turret. The annotation says, 'observation post on top of the car, with a rising chair. Keyboard to type in place-names for information.'](image)

6.4.2 Types of context indicators

In order to increase the understanding of the characteristics of context indicators, and to explore the proportion of links that are backed up by context indicators, the links in both the brainsketching and the brainstorming with post-its segments of two of the experimental meetings (meetings 1 and 2) were examined. The analysis was limited to the investigation of context indicators for relatively certain links, which consisted of the links that were registered by both the researcher and the observer. For each link, the videotape was inspected in order to identify context indicators. These context indicators were clustered, which resulted in nine context indicator types:

1 Time

This relates to the time span between the sharing of the prior idea and starting the notation of the new idea. A short time span can provide an indication for linking.

Five minutes into the brainstorming with post-its segment of meeting 1, designers A and B both want to explain an idea. Designer A first explains her idea, 'communicating through a head-set' (idea 19). As designer B hears the word 'communicating', she becomes visibly anxious to express of her idea. She quickly hands her idea to the facilitator and then starts writing. Before any other group member provides an idea she shares her next idea, 'cellular phone' (idea 21). This whole episode takes less than thirty seconds. This provides a context indicator, as no new information was provided in the time interval between the occurrence of ideas 19 and 22.
2 Inspection
Designers seek inspiration by inspecting previous ideas on the posted flipcharts.

In the brainstorming with post-its segment of meeting 2, designer F inspects the flip chart with post-its for ten seconds. One of the ideas on the flip chart is designer K's idea 'a street plan on the floor'(idea 20). After inspecting, designer F directly starts writing down his idea: 'making a route map for your father'(idea 25).

3 Physical reaction
Frequently there is a physical reaction when an idea mentioned triggers a new idea, such as moving from a reclined position into a more active position.

In the brainstorming with post-its segment of meeting one, designer C just sits back after explaining an idea. When designer A explains her next idea, 'spinning on your chair' (idea 55), C turns his head abruptly. He looks at A and then moves his body up and forward before starting to write down his idea: 'rocking chair' (idea 58).

4 Verbal reaction
These are spontaneous statements that happen right before the designer makes a notation of the new idea. Common are verbal reactions like "oh .. yes".

When, in the brainstorming with post-its segment of meeting 2, designer F shares his idea: 'making a route map for your father'(idea 25), designer G reacts immediately: "a treasure map or something". After this impulsive reaction, he actually writes down the idea (27), and explains it upon finishing writing.

5 Withdrawal
The designer may withdraw, or 'freeze' after an idea is mentioned and then come up with a related idea some time after. It appears that the designer takes in the information and then withdraws to process it, and then generate a new idea that builds on the earlier one.

During the brainstorming with post-its segment in meeting 1, designer A explains his idea 'animal parts on the ceiling'. Then he is lost in thoughts, moving his hands in support of his thoughts. He then starts inspecting one of the flip charts with earlier ideas on the wall. He ignores designer E explaining an idea, then he springs up, being triggered by an idea on the flipchart (likely to be idea 24, 'tossing a ball back and forth'). He stares at his book of post-its for a few seconds, ignoring designer B explaining her idea (47). Then he starts writing. After explaining his idea (50), 'ball sticks to the ceiling when thrown', he sits back, and examines the present flipchart to catch up on ideas that, apparently, he missed while developing his own idea.
6 Explanation

In explaining their ideas the designers use words that connect their idea to earlier ideas. Utterances like "This idea builds on that one" or "I liked that idea, so I came up with this one", make up this category of indicators.

"In meeting 1 at the end of the brainsketching segment, designer D explains his idea (47), 'racetrack for planes on the ceiling'. He says: "I also really liked that one, that idea for a racetrack on the roof. You could do that with airplanes, because they are in the air anyhow". From his explanation it becomes pretty clear that D’s idea 47 builds on idea 5, ‘racetrack upside down on roof’ that designer C sketched earlier (see figure 6.16).

7 Addition

Designers draw arrows or lines to indicate connections between ideas.

"See figure 6.16. Designer D develops his previous idea of the racetrack with airplanes. By means of an added arrow, he points out the connection between the two ideas.

8 Location

The target idea is positioned very closely to the source idea, even when the usual order of idea production would suggest a different position on the flipchart.

"Designer D writes down his idea 47 very closely to idea 5, providing an annotation to the ‘racetrack on the roof’ idea. See figure 6.16.

9 Scheme resemblance

These indicators consist of a resemblance in the notations on the paper, instead of the content or the meaning that these notations carry.

"In the brainsketching segment of meeting 1, designer E sketches ‘a car cockpit surrounding the child’ (idea 9). In the next round of generating ideas, designer D comes up with an idea for a ‘real mini-office’ (idea 21). The characteristics of the sketch of idea 9 are likely to have triggered the sketchpad idea. There is a resemblance in the characteristics of the sketch, while there is hardly any resemblance in the ideas themselves. (see figure 6.17)

Usually, separate indicators do not provide sufficient proof of linking. As in the gun turret example mentioned earlier (figure 6.15), links are determined by combining evidence provided by various indicators, both on the content level and on the context level. For instance, a ‘location’ indicator reinforces the ‘scheme resemblance indicator’ in the previous example (figure 6.17): the sketches of the car cockpit and the mini-office are positioned closely together on one flipchart.

The occurrence of these context indicators was calculated for each of the brainstorming with post-its and brainsketching segments. The results are presented in figure 6.18:
For brainsketching, the three most frequently recognized indicators are ‘explanation’ (30%), ‘inspecting’ (17%), and ‘physical reaction’ (16%). For brainstorming with post-its, the two most frequently recognized indicators are ‘time’ (34%) and ‘physical reaction’ (29%). The ‘addition’, ‘location’, and ‘scheme resemblance’ indicators almost exclusively occur in the brainsketching segments. This is not surprising, as they relate to clues for links that are situated on the flip charts. Also indicator 6, ‘explanation’, is mostly noticed during brainsketching segments. As the explanation of ideas is separated from the idea generation in brainsketching, designers tend to describe where their ideas originated. Because of the high speed of idea generation during the brainstorming with post-its segments, the designers tend to solely mention the idea without references to the way in which the idea originated, which results in a less frequent occurrence of the explanation indicator in the brainstorming with post-its segments.

Indicator 5, ‘withdrawal’, is found exclusively in the brainstorming with post-its segments. ‘Withdrawal’ is an indication that a designer retreats from the group process into his or her individual idea generation process. During the rounds of generating ideas during brainsketching, the designers generate ideas by themselves. As the designers are already involved in an individual process, the ‘withdrawal’ indicator is not likely to be encountered during brainsketching. To a lesser extent, the same is valid for the ‘time’ and ‘physical reaction’ indicators, which refer to direct reactions to ideas generated in the group as well. As the explanation of the ideas and the generation of ideas are separated in brainsketching, these indicators are less relevant.

\textbf{Ratio of links supported by context indicators}

For the two meetings, the strength of the context evidence was determined for the links that were recognized by both the researcher and the observer. A link was considered to have strong context evidence when there was more than one context indicator present, or when a single context indicator provided very strong evidence. The example of the ‘gun turret’ idea used earlier (see figure 6.15) has three context
indicators: a 'verbal reaction' (designer D shouts 'Yes!' in reaction to the see-through turret idea) a 'location' (idea 45 is positioned very closely to idea 44, in fact, idea 45 provides an annotation to idea 44) and an 'explanation'. (Designer D points at idea 44 and mentions 'that one (points at idea 44) combined with that one (points at idea 35: virtually shooting other road users)'). An example of a link with a strong single context indicator is designer C's idea 'swing on the ceiling' (idea 60) in the brainstorming with post-its segment of meeting 1. This idea builds on designer D's idea 'spinning in a chair' (idea 55). The link has a single strong 'physical reaction' context indicator: When designer C explains his idea, designer D makes a sharp turn with his head. He is absolutely motionless for a brief moment and then moves forward and up before he starts writing down his idea.

The results of this investigation are shown in figure 6.19:

![Figure 6.19: Ratio of links identified by both the researcher and the independent judge, which are supported by strong context indicators.](image)

These results suggest that agreed links are frequently founded by strong context evidence. For the four segments, between sixty and eighty percent of the clear links were founded by strong context indicators. Context evidence appears to be especially relevant for the brainsketching segments, where in both meetings more than eighty percent of the clear links were supported by strong context indicators.

Only links noted by both the researcher and the independent judge were inspected for the presence of context indicators. Between twenty and forty percent of these links would remain unnoticed if the linking was only decided on by means of the presence of clear context indicators. This suggests that determining links in a link matrix solely based on context indicators would disregard too many links to provide an informative system of connections made in the idea generation process. However, the nine types of context indicators identified can provide valuable additional information that can strengthen the confidence in the links found.
Further speculations on the brainsketching technique

Stimulating group reflection

The 'magical moment' for brainsketching, in which group members share their ideas before going into the next round of idea generation, has more potential than used so far. In the brainsketching technique applied in the second study, this moment was just used for the designers to briefly explain their ideas. During these moments, the designers listened as one at a time they shared their ideas. We called this 'inspection', as the designers scan the ideas mentioned for interesting new directions. Then, in the next round of generating ideas, the designers could start with further interpreting the interesting ideas found and generating new ideas.

It may be possible to make more use of the step of sharing ideas as a group activity, by more actively engaging in a constructive group reflection on the ideas generated. Considering the fact that brainsketching may involve a more deliberate and developmental idea generation process, such moments of creative interaction between designers - which in the present technique are not solicited during the rounds of idea sharing - can be used more deliberately as an essential element of the brainsketching technique. In the present brainsketching technique, designers are discouraged from digressing into discussion in the periods for sharing ideas. Sometimes, however, the designers could not be stopped. A good example is found in meeting 1 of the second study (see Chapter 5). The relevant ideas for this example are provided in table 6.1:

<table>
<thead>
<tr>
<th>Idea/Person/Chart</th>
<th>Label</th>
<th>Time / protocol text</th>
<th>Sketch (translation of annotations)</th>
</tr>
</thead>
<tbody>
<tr>
<td>35/C/I</td>
<td>Virtual shooting other road users</td>
<td>54:29</td>
<td>C: I thought... yes... the youth of today is getting more aggressive anyway, so if you can make some kind of a virtual picture on the window, which you can shoot at... and that it can kind of recognize the outline of the surroundings and that you get to hear through the headset that someone is hit or that the target is destroyed or something... that you can interact with the surroundings by shooting at it (+ headset, sound effects when you hit someone) (virtually shooting other road users)</td>
</tr>
<tr>
<td>44/C/II</td>
<td>Seat rises into observation turret</td>
<td>1:00:07</td>
<td>C: I thought that in the back... if you make a chair that comes up automatically, into a glass- or see-through turret... that you can see beyond the whole car. Then you can see the signs with city names better. And you can type those into a key-board immediately... (observation post on top of car with chair that rises up) (keyboard to type in town names for information)</td>
</tr>
</tbody>
</table>
While designer C is explaining his ‘observation turret’ idea (see table 6.1 and figure 6.15), designer E makes a verbal remark of adding a gun to the turret. Then designer D pretends to be playing with a gun turret. He does not appear to try to communicate through his gestures; the gestures appear to be some kind of simulation in support of his individual process. After C is done explaining his idea, designer D explains how the earlier idea 34, ‘virtually shooting other road users’, in combination with idea 44, can provide a gun turret game. The facilitator then asks C to add an annotation of that idea to designer C’s sketch of the observation turret.

While D is doing this, designer A suggests developing this idea into a computer game, ‘car wars’. In this moment of sharing ideas, all of a sudden there is a lot of interaction taking place and energy in the room. There is laughter and quick verbal responses and four out of five designers pretend to be holding and shooting toy machine-guns. Instead of seeing such moments as an irregularity in the brainsketching process, such moments might be fostered as moments of creative group interaction.

In her research on the reflective practice of design teams, Valkenburg (2000) uses Schön’s (1983) ‘reflective practice’ theory of designing. She reports:

Schön’s basic assumption is that the designer determines his position in the design situation. By interpreting the design situation in his own subjective way, the designer creates a context for further activities. By constantly considering his activities and their implications, the designer can adjust the activities, or adjust his interpretation of the situation. (p.229)

Valkenburg stresses the importance of framing and reflecting in team design activity. Reflection, in Schön’s opinion, relates to evaluating, for example, the appropriateness of the design activities that are taking place, rather than judging the quality of the ideas generated. Framing relates to (temporarily) following a certain guiding principle for focusing the design activities. Valkenburg provides the following interpretation: “Schön does not provide a clear, concise definition of the term ‘frame’. From the publications we can figure out that frames are sense-making devices that establish the parameters of a problem” (p.74).
Frames can be detected throughout idea generation meetings, but they are not explicitly used as a device for structuring the idea generation activity. The absence of the explicit use of frames may be related to one of the main criticisms of Nijstad (2000) regarding brainstorming meetings. He describes the brainstorming process as a sequence of ‘trains of thoughts’. According to him, such a ‘train of thought’ is:

... a rapid accumulation of semantically related ideas. When such a train of thought no longer leads to new ideas, a new search of memory is undertaken, which may lead to the activation of a new image. This, in turn, may lead to a new train of thought. This process continues until the brainstorming session is ended (p. 139).

As a possible explanation of production loss in brainstorming groups, he proposes that such trains of thoughts are prematurely aborted when an idea cannot be expressed immediately, because the group member has to wait to take his turn. If we assume that a ‘frame’ shares much of the characteristics of such a ‘train of thought’, then during an idea generation meeting a ‘frame’ may be prematurely abandoned, just because another group member starts a new line of associations. Possibly, by dealing with frames more deliberately, a more directed and well-integrated search for ideas can be achieved.

For brainsketching, this could mean that rather than merely inspecting the group’s ideas for leads to further individual idea generation and interpretation, the designers could interpret and reflect on their ideas together. After such a step of group reflection, the designers could return to their individual idea sketching accompanied by a shared understanding of the directions for further idea generation.

If the brainsketching technique included such an activity of group reflection, the ‘gun turret’ example discussed before (see figure 6.15 and table 6.1), could have been dealt with by the designers recognizing a ‘frame’ of ‘virtually shooting other road users’. Then, the designers could have determined whether this frame was sufficiently explored by proposing a gun turret and a ‘car wars’ video game, or whether in the next idea generation round efforts should be made to further explore the frame, and if so, which are interesting directions. Then, in the next round of generating ideas, the designers could have returned to their individual idea generation, but with directions that were generated in the group, for instance, to further explore video games in which the Vista car is the subject.

### 6.5.2 Applicability of brainsketching for participants without a design background

The studies performed involved advanced product design students, who have at least basic sketching skills due to their education. In the first two years of the program, Delft product design students receive about 120 hours of drawing instruction.
We already mentioned that in practice, design teams are often multidisciplinary in nature (see section 1.3), with for instance, designers, marketeers, and engineers working together. This means that in design practice, often, designers and non-designers will participate together in idea generation meetings. The question remains whether non-designers are able to fully participate in techniques that involve sketching. Non-designers themselves tend to be eager to disqualify themselves; when asked to make a sketch of a certain topic, many people tend to respond with resolute remarks like, ‘Oh, but I can’t draw!’

In theory on design sketching, the designers’ ability to sketch is highly valued. For instance, McKim (1980) stresses the importance of drawing skill:

...the importance of drawing skill to the full expression of visual ideas must not be overlooked. Inadequate drawing ability has three negative effects...:
(1) a clumsy sketch can evoke judgmental processes that restrict or stop idea-flow.
(2) ideas that cannot be adequately recorded in sketch form are often lost, and
(3) attention devoted to problems of drawing is attention diverted from idea generation. (p. 125-127)

Muller (1997) suggests:
...it can be expected that poorly developed [drawing] skills lead to representations that are difficult to interpret. That results in a shift in focus from the design problem towards a representation problem. This results in a process of idea development that is slow to pick up speed... (p. 32, translated from Dutch)

An initial suggestion regarding the relative importance of drawing skill for idea generation meetings in which sketching is used as a working medium is found by re-analyzing the link matrices in the second empirical study. For each designer the forelink density in the brainsketching condition was determined. The forelink density is the number of links that are made with ideas generated by the designer, divided by the number of ideas generated by the designer. The forelink density indicates the extent to which the designers’ ideas are connected with during further idea generation. One may expect that ideas from designers with good sketching ability are used more often for making connections than ideas from designers with poorer sketching ability. Better quality sketches look more attractive, which may draw attention to the idea, and the information conveyed through the sketch may be more easily accessible. But, contrary to expectations, the self-perceived sketching qualities and the forelink density did not correlate at all (R=.016, p=.50) for the brainsketching technique. Of course, the subjects used were all design students with at least a basic ability to make design sketches. Even so, the absence of a positive correlation does indicate that the ideas by the better sketchers did not get more connections than the ideas by the poorer sketchers. Perhaps, in these early phases of generating ideas, the quality of the sketches are not very
important, especially if the participants have the opportunity to explain their idea sketches.

In various creative problem solving meetings that I have facilitated in the past years, I have included techniques that involve sketching, among which the brainsketching technique. Usually these were meetings within the domains of engineering and marketing, with participants from a variety of backgrounds. My experience is that non-designers can very well engage in sketching activity, provided that they are given the proper directions.

The main problem encountered, when applying brainsketching in groups with non-designers, is that these participants are inclined to immediately accept the first idea sketch on the paper as the basic direction for further idea generation. For instance, brainsketching was applied during a new business development meeting of a large Dutch consumer products company. The goal of this meeting was to explore opportunities regarding ‘health monitoring’. After an initial step of redefining the problem, the group members generated ideas by using an adaptation to brainsketching in which participants were asked to sketch ideas in pairs. Four rounds of generating ideas took place. In between rounds the participants were asked to briefly explain their ideas. Figure 6.20 shows one of the resulting flipcharts.

In this meeting, the participants tended to use the previous ideas as a frame for further idea generation. They tended to make amendments to earlier ideas, without challenging the frame set by the earlier idea. In the example, the initial idea sketched was to perform health monitoring through a ring on one’s finger. In the next rounds, various additions were provided. For instance, having medication in the ring, in order for the ring to not only function as a monitor, but also as a dispenser. Another idea was interaction with the health monitoring through a personal computer. The only idea that does not assume the ‘ring’ idea as the basic direction is the idea in the bottom-left corner, which involves a gate for scanning the health of whoever passes through. Perhaps the group member who generated ideas magnified the ring to such dimensions that one can walk through it. Such operations are suggested by creative problem solving techniques like ‘Scamper’ (Eberle, 1971).

Two possible reasons for this early fixation taking place are: 1) It requires effort for the participants to set up an entirely new sketch. Using an existing idea as a basis for sketching, and making adjustments to that earlier sketch is much easier. 2) Because a sketch provides an idea with more detail than written notations, participants are not able to reflect on the idea in any other way than by judging it. Unlike the designers, the participants are unable to regard the sketch as a mere snapshot of an idea generation process, and interpret it accordingly.

The following guidelines for using idea generation techniques that involve sketching with non-designers have helped me to overcome the difficulties of using brainsketching with non-designers:
1. **Proper warming-up activity.** To take away apprehension of using sketching as a means for expressing ideas, a warming-up activity is needed. Such an activity can show that non-designers can properly communicate through sketching, and that the quality of the sketch itself is not so important, because much of the information contained in a sketch is provided when the participant who drew the sketch explains it. For instance, the following two sketches (figure 6.21) were part of a warming-up activity in an idea generation meeting. The participants were asked to make a quick sketch of a 'thumbs-up' feeling that they had experienced in their lives, without drawing any thumbs. The explanations of the participants are provided with the pictures:

![Sketches and Explanations]

By producing such kinds of warming-up sketches, the participants get comfortable in using sketching as a working medium for expressing thoughts. Any apprehension with sketching among the participants can be dealt with before getting involved in the actual idea generation.

2. **Emphasizing interpretation and exploration of ideas, rather than evaluation of ideas.** As the participants may be inclined to assess the value of the idea sketches as finished product proposals, it is especially useful to ask the participants to stay away from value judgments regarding the quality of the idea. Ask the participants to freely imagine the consequences, or suggestions that the idea sketch provides for the generation of new ideas instead. Questions like, 'What unique qualities are in this sketch that you would like to explore further?' direct the participants towards constructive interpretation, rather than critical evaluation of the idea sketches produced.

3. **Invite making new drawings, rather than drawing on the existing one.** If participants are very focused on working within the same basic sketch, one can ask them to make new sketches, instead of adding features to the earlier sketch. This can even provide a steering mechanism: Drawing on the existing sketches emphasizes idea development. And, making new sketches emphasizes differentiation of ideas, as participants will not be inclined to produce a replica of the existing sketch.
Recommendations for further research

In addition to providing some answers to the research questions, this research project has opened up new directions for further research. Some of these directions are related to the limitations of the process indicator-based research method that was used to interpret the empirical data. Other directions are related to interesting topics for further research that emerged through interpreting the results of the empirical studies. A few of the questions to be answered by further research follow:

**Can an individual cycle of re-interpretation be detected within the brainsketching process?**

In Chapter 2, we identified the possible presence of an individual re-interpretive cycle within group design meetings, and in Chapter 6, we attempted to gather empirical evidence in order to learn more about the potential presence of such a re-interpretive cycle during brainsketching. We detected a relatively high level of tangential links within the individual-direct linking, which is regarded as an indicator for re-interpretation taking place. However, the approach to linkography used in this thesis is based on determining general link indicators, which did not allow for the close inspection needed to identify such athing as a cyclical movement in the idea generation process. To investigate whether a cyclical generate-interpret reasoning process is taking place while the designers are idea sketching during the brainsketching technique, additional experimental meetings need to be set up. In these meetings, designers could be asked to think aloud while idea sketching (we will not go into detail here regarding the obvious practical difficulties of such an experimental design). Or, perhaps there are other means of accessing the designers’ reasoning processes while idea sketching.

**What is the relationship between the quality of the linking process and the quality of the resulting ideas?**

Linkography has proved to provide a good overview of the process characteristics of idea generation meetings. It helped to identify differences in idea generation processes, when sketching or written language is used as a working medium. In this thesis, we made the assumption that ‘integratedness’ of idea generation process is a measure of the quality of the idea generation process. This assumption needs to be verified by relating the process characteristics of idea generation meetings - measured by the link indicators- to the characteristics of the resulting ideas, measured by, for instance, the creativeness of the ideas (Besemer & O’Quinn, 1986; Amabile, 1996). Gaining a further understanding of this relationship between the qualities of the process and the qualities of the ideas, will enable us to draw more definite conclusions regarding the qualities of the idea generation processes for the working media of sketching and writing.
What are the functions of sketching in idea generation meetings within the context of product design projects?

Applying sketching as a working medium in idea generation meetings may have additional functions for design team projects, as well as functions for the idea generation process itself. The empirical studies in this thesis consisted of isolated experimental idea generation meetings, which only allowed us to investigate the role of sketching within the idea generation process itself. In a real design situation, the use of sketching as a working medium may have additional roles. Exploratory interviews with experienced practicing facilitators suggest that visualized ideas tend to ease the transfer of ideas into the company and thus stimulate implementation of the ideas. Compared to sentential descriptions, good quality idea sketches are easier to understand, more attractive, and appear to be more substantial or feasible.

For instance, the sketches in figure 6.22 were made at the end of a idea generation meeting for a home appliance company. Translating the ideas into cartoon-like pictures helped to get product managers—who themselves had not taken part in the idea generation meeting—interested in these ideas regarding new uses for television.

What are the functions of idea generation meetings in the context of team design projects?

By interpreting the results of the empirical studies, we detected possible differences in applicability of idea generation meetings. Sentential techniques appear to provide a wide range of ideas, and therefore they are more appropriate when a quick scan of the solution space is desired. Graphic techniques appear to provide fewer, but more developed ideas, and are therefore better suited to provide a preview of the consequences of various directions for generating ideas. This could be useful when the goal of the meeting is more related to starting up a team project, rather than the traditional role of idea generation meetings in design, which is, to generate many ideas, from which the designers can select ideas for further development. An exploratory survey performed in the beginning of this research project, indicated that the most important reason for product designers to call a creative problem solving meeting was related to group issues such as, team building and providing commitment to the problem among the group members (Van der Lugt & Buijs, 1998). Such group related functions of idea generation meetings may be more valuable when starting up design teams than the quality or quantity of solutions generated. Few efforts have been made to investigate these additional functions of creative problem solving meetings. For an example of such a study, see Sutton & Hargadon (1996) who investigated the additional functions of creative problem solving meetings within the IDEO design agency (see section 1.3).

Re-assessing the functions of creative problem solving meetings—beyond the
quantity and quality of ideas generated—provides a promising new direction for further research. Gaining a further understanding of these additional functions of creative problem solving meetings within the context of design team projects, may lead to the development of methods for creative problem solving meetings that more specifically address these team-related issues.

Notes:

1 The Cohen's Kappa measure of inter-rater agreement used is intended for categorical data. As the link types are part of a spectrum, there will always be problems at the boundaries between adjacent link types.

2 The link density for brainsketching was found to be significantly higher compared to brainstorming, see section 5.5.


4 For instance, Suwa & Tversky (1997) asked designers to produce retrospective reports while watching the videotape of their own design activities. The researchers then analyzed the protocols of these retrospective reports.
Glossary of introduced terms

Content indicators provide evidence for a link that relates to similarities in subject matter between the ideas.

Context indicators provide evidence for a link without relating to the subject matter. Such situational evidence can, amongst other things, consist of gestures, body movements or remarks made by the designers.

The task-related information produced by the designers and available to them. In idea generation meetings, the external memory mainly consists of the posted flipcharts with ideas. Four different areas of a group's external memory were identified:

- The Individual-Direct area is directly available to the individual, for example, an individual sheet of paper that a designer is working on.
- The Individual-Remote area is only available to the individual designer, but is not under the direct attention of the designer, for example, the sheets that are covered by the designer's current worksheet.
- The Shared-Direct area is directly available to all the group members, for example, the notations made on a whiteboard in support of a group discussion.
- The Shared-Remote area is available to the group members, but it is not under the direct attention of the group, such as sheets of previous ideas that are posted on the walls.

Creative problem solving meetings that focus on activities in the 'generating ideas' component.

A link shows a connection between two ideas, signifying that the latter of these two ideas can, at least partly, be attributed to the presence of the earlier idea.

Links can be related to the source idea's location in the group's external memory of the source idea. As well as giving information about the level of interpersonal and self-linking, these link densities say something about whether the idea generation process taking place is mainly based on immediate connections, or on more retrospective connections made.
**Link density**  
"The link density (LD) divides the total number of links in an area of a link matrix by the total number of ideas in that area. Link density is a relative measure for the integratedness of the idea generation process. It provides an indicator for the way in which the "seeking combinations" guideline for divergent thinking is followed.

**Link matrix**  
A link matrix is the name for the graphic display for a linkograph used. In a link matrix, rows and columns represent ideas. A link between two ideas is marked by a black box where the resultant idea (represented by the column) meets the source idea (represented by the row).

**Link type indices**  
The link type indices indicate the proportions of the kinds of connections that exist between the source ideas and the resultant ideas in a link. The following three link types were identified:
- **Supplementary links** relate to small and auxiliary changes. The relationship between ideas is based on minor improvements on the same general idea.
- **Modification links** provide structural changes in the idea, while maintaining the existing line of thought. Some major aspects of the source idea are still present in the resultant idea.
- **Tangential links** indicate connections between ideas that do not share any of each other's direct functions. Most tangential links result from free association.

**Resultant idea**  
The resultant idea is the later of the two ideas in a link. The later idea is, at least partly, the result of connecting with the source idea.

**Source idea**  
The source idea is the first idea in a link between two ideas. The presence of the resultant idea can, at least partly, be attributed to the presence of this first idea.

**Self-link index**  
The proportion of links that designers make with their own ideas is referred to as the **Self-Link Index (SLI)**. In a 'full' group situation, the designers build on the generated ideas regardless of who conceived of them. A low Self-Link Index indicates a lot of building on each other's ideas, and therefore signifies a well-integrated group process. A high Self-Link Index indicates a high proportion of individual idea generation processes taking place in parallel, which is a sign of a poorly integrated group process.
Summary

Introduction

Creative problem solving meetings have become a customary method for generating design ideas. Perhaps this is due to the increasingly team-oriented nature of design activity. This thesis focuses on the activity of generating ideas within such meetings, therefore they are referred to as idea generation meetings. In the existing body of idea generation techniques, the primary mode of expressing ideas is in written language. Customarily the facilitator of the meeting writes down brief descriptions of ideas on a flipchart. In contrast, when involved in unstructured design meetings, designers tend to make extensive use of sketching when generating design ideas. Design researchers have often connected this activity of sketching to creativity in design. The ambiguous characteristics of sketches particularly are regarded to stimulate new interpretations of the marks made on the paper.

As both sketching and idea generation techniques are regarded to be tools for stimulating creativity in design, perhaps combining them may provide an even better tool. This lead to the original objective of this research project, which was to investigate whether including sketching in idea generation techniques would enhance their applicability as design methods. Probably, idea generation meetings have been incorporated as design methods without a critical review of the mode of expression used. If this is the case, adjusting the method to the specific conditions of the domain could enhance its applicability to the design domain.

The search for answers is structured by means of two main research question. The first research question is related to investigating how different ways of including sketching into idea generation meetings may enhance or obstruct the process:

RQ 1: How do various ways of including sketching in idea generation meetings influence the group's idea generation process?

The second research question attempts to gain a more thorough understanding of the ways in which including sketching changes the structure of the idea generation process:

RQ 2: What are the differences in the structure of idea generation processes, when sketching or writing is used as a working medium?

In order to be able to answer the main research questions, a research approach needs to be developed that allows for determining the characteristics of the idea generation process. The majority of the methods available for assessing creative problem solving meetings compare the outcomes of different experimental
treatments, usually the quantity and/or quality of the ideas generated. The results-oriented approach is popular because of its robustness and its academic credibility. However, by discarding the process itself as an object of research, the results-oriented approach leaves a rich source of information unutilized. If we are interested in the creative problem solving process, it is more informative to investigate the process itself, rather than investigating its results. This leads to a third, additional, research question that deals with developing a research method that provides insight into the characteristics of idea generation processes:

**RQ 3:** How can the idea generation process be described in such a way that differences in these processes can be analyzed, in order to answer the questions regarding the role of sketching in idea generation meetings?

Below, the conclusions regarding these three research questions are summarized. We start with the research approach related question, as this question provides an understanding of the way in which we analyzed the data. This provides insight into the way in which we reached the conclusions regarding the main research questions.

**How can the idea generation process be described in such a way that differences in these processes can be analyzed?**

Within the field of creativity research we were not able to uncover any research methods for analyzing the structure of the idea generation process. However, within the adjacent field of design research, Gabriela Goldschmidt developed linkography as a method that specifically focuses on the structure of the problem solving process. In linkography connections -or links- between design moves are analyzed to investigate structural patterns in design reasoning.

Linkography was further developed as a method for assessing the idea generation process by means of investigating the connections between ideas made in the idea generation process. Linkography was adapted and developed by studying links between 'ideas' rather than 'design moves' and by providing some basic indicators for links. The role of context indicators -indicators for links that do not refer to similarities in subject matter of the ideas- especially was found to provide important support when determining links. Nine categories of context indicators were identified: 1) Time between the two ideas; 2) Inspection of earlier ideas; 3) Spontaneous physical reaction; 4) Spontaneous verbal reaction; 5) Withdrawing oneself from the group process to ponder; 6) Making a connection in the explanation of an idea; 7) Making a connection by a mark on the paper; 8) Location of the idea on the paper; 9) Resemblance in notation of the ideas. These categories can be used to develop better-defined guidelines for determining links.

Applying linkography to compare the processes of idea generation meetings imposed three criteria. First, the graphic display used needed to be accessible. The display needs to provide an objective overview of the linking process and it needs
to be easily understood by other researchers. Secondly, the linking display needed to be flexible. We used the linking display for many analyses, such as determining the link density, self-linking and link type indices, but also to determine the inter-rater agreement. The linking display used needed to be flexible enough to allow these various kinds of analyses. Finally, the linkography approach used needed to provide results that could be compared between meetings. The linkography method was adapted and modified to meet these criteria.

To meet the accessibility and flexibility criteria, we presented linkographs in a matrix format. In addition to being a familiar display for presenting research data, the matrix format allowed for easy operations and calculation of link indicators. We used and developed various indicators for linking to allow unbiased comparison between meetings. The following indicators were used and developed:

- **The link density** is an indicator of the integratedness of the process. A high link density indicates that ideas have many connections with earlier ideas.

- **The self-link index** is the ratio of links that the designers make with their own earlier ideas, in relation to the total number of links made. Together with the link density, the self-link index indicates to what extent the ‘building on each other’s ideas’ guideline is met.

- **The link-type indices (Supplementary, Modification, and Tangential)** indicate the nature of the connections that are made. Tangential links indicate wild leaps into a different direction, modification links indicate direct variations and supplementary links indicate small alterations.

- **The link densities for various areas of external memory specifically address the different interactions with notations made in ‘external memory’**. Four categories of links were defined, which differentiated between direct and remote links made, and between individual and interpersonal links made with ideas in external memory.

Linkography is a research method in development; many questions regarding the application of the method remain unanswered. However, the method provides a valuable alternative for more traditional outcome-focused research designs. Constructing link matrices is a fairly laborious task, but it provides good insight in the differences between idea generation processes.

**How do various ways of including sketching in idea generation meetings influence the idea generation process?**

In the design thinking literature, we detected three principal themes regarding the ways in which sketching may contribute to the creative processes of design teams:

1. Sketching supports a re-interpretive cycle in the individual designer’s thinking process; while a designer is sketching he or she is continuously observing and interpreting the consequences of the marks made on the paper.
2. Such re-interpretation can also occur when designers discuss design ideas. Designers can interpret sketches differently and by doing so open up new directions for further inquiry.

3. Sketches stimulate the use of earlier ideas by enhancing their accessibility.

In order for these functions of sketching to also apply for idea generation meetings, the process of idea sketching needed to be compatible with the process of divergent thinking. This meant that, when compatible, the idea generation process should not degrade when sketching is included, rather, the idea generation process should improve. In Study One (Chapter 4), three graphic variations to the brainstorming technique (in which sketching was used) were applied in experimental meetings. In a fourth meeting regular brainstorming was applied as a control condition. The fully graphic variations performed substantially less well on parameters that reflected the four guidelines of divergent thinking, compared to regular brainstorming. Not only did the graphic variations produced substantially fewer ideas, but their link densities were also lower, which meant that the idea generation process was less integrated. This lead to the conclusion that the processes of idea sketching and divergent thinking are not fully compatible.

Because of the encountered incompatibility, we could not verify whether the three purported theoretical functions of sketching for design groups were also applicable for idea generation groups. However, by further analysis of the data from the second empirical study we could revisit these functions. The results of this additional study show that there is some evidence in support of the first function, sketching stimulating a re-interpretive cycle for the individual designers. For example, the tangential link type index was higher than average for the links with ideas in the individual-direct area of external memory. No support was found for the second function, which suggested that the group members re-interpret each other's ideas through sketching. Some support was found for the third function, the increased use of earlier ideas because of the enhanced accessibility. For, the link densities for ideas in the remote areas of external memory were substantially higher for the sketching condition.

What are the differences in the structure of idea generation processes, when sketching or written language is used as a working medium?

On detecting incompatibility between the activities of idea sketching and brainstorming in the first empirical study, the search was redirected towards achieving a more thorough understanding of the nature of the differences in structure of the idea generation processes, when sketching or writing is used as a working medium. In the second empirical study we compared the processes of two techniques that were considered to represent the working media of writing and sketching. Brainstorming with post-its was found to be an appropriate
representative of sentential idea generation techniques. A variation to the brainsketching technique was developed to provide an appropriate representative of graphic idea generation techniques. The existing version of brainsketching was entirely non-verbal. Participants sketch their ideas individually on large sheets of paper pasted on the wall. After a few minutes, the participants switch places and continue sketching, while using the ideas drawn on the sheets by other group members as a source of inspiration. Usually about five such rounds take place. To provide an appropriate representative of graphic group idea generation, a more group-oriented technique was required. In the variation to brainsketching that we developed, which we referred to as 'interactive brainsketching,' participants briefly present their ideas to each other in between rounds of idea sketching. A small pilot showed that compared to 'regular' brainsketching, the participants were found to make substantially more connections with each other's ideas when using interactive brainsketching.

What, then, were the differences found? The link type indices show that the sentential idea generation process - of which brainstorming with post-its was a representative technique - involves a broad search for new directions (marked by tangential links) supplemented by brief explorations of some of these directions (marked by modification links). Hardly any idea refinement (marked by supplementary links) takes place. This is in line with what one would expect when considering the guidelines for divergent thinking. The graphic idea generation process was found to include more integration of the earlier ideas and more idea development and refinement, while maintaining a ratio of new search directions that is similar to the brainstorming with post-its technique. For, the tangential link type indices for brainsketching and brainstorming were found to be comparable. Graphic idea generation techniques can be considered to represent a design-like problem solving process, which is signified by a search for various novel directions, followed by an exploration of some of these directions, and finishing with incremental development of a few ideas.

**Conclusions**

The different characteristics of the graphic and sentential process suggest that they may serve different purposes as design methods. Sentential idea generation may better serve the traditional role of creative problem solving techniques in design methodology, which is to generate a large number and variety of design ideas, of which some can be selected to further develop into design solutions. Graphic techniques may be more suitable when, instead of a large number of ideas, a smaller but more refined collection of novel design ideas are desired. For instance, graphic techniques can be applied in a design project start-up meeting to provide a quick simulation of the design process to come. Such a simulation allows the
designers in a team to gain a shared understanding of the design task by discussing possible pathways towards solutions that came up when generating ideas.

As the existing guidelines for divergent thinking are instrumental to sentential idea generation, an alternative set of guidelines was proposed to support the different structure of the graphic idea generation process. These guidelines stress the importance of interpreting the generated ideas, and making connections:

- **Build on each other’s ideas.**
  
  Inspect each other's ideas for information that can be useful for integrating into new ideas.

- **Interpret ideas constructively.**
  
  Interpret ideas by seeking suggestions or directions for further idea generation, rather than assessing and estimating the value of the idea as an artifact. This guideline stimulates a directed search into new directions.

- **Strive for ideational fluency.**
  
  Stay away from over-developing or keeping interpreting sketches of single ideas. Try to accomplish a flow of idea generation, in which you swiftly move between producing ideas and interpreting them to gather clues for further idea generation.

- **Look for wild connections, especially when interpreting your own ideas.**
  
  Make sure that you share and interpret your wildest ideas, because they can lead towards interesting new directions.

It can be concluded that applying sketching in idea generation meetings does not necessarily provide a better idea generation process. Instead, it leads to a structurally different idea generation process. This graphic idea generation process could provide a valuable alternative to designers, especially when considering the proposed differences in applicability.
Samenvatting

Schetsen bij ideegeneratiesessies in het ontwerpen

Inleiding

Creativiteitssessies zijn uitgegroeid tot een geaccepteerde en populaire methode voor het genereren van ontwerpideeën. Mogelijk komt dit doordat ontwerpen steeds meer in teams plaatsvindt. Dit proefschrift richt zich op de activiteit van het ideeëns genereren binnen zulke creativiteitssessies. Daarom worden ze hier 'ideegeneratiesessies' genoemd. Bij verreweg de meeste bestaande ideegeneratietechnieken is geschreven taal het voornaamste medium; de facilitator noteert gewoonlijk de ideeën die geuit zijn door de groepsleden op een flip-over. Ontwerpers zelf daarentegen maken, als zij aan het ontwerpen zijn in groepsverband, veel gebruik van schetsen. De activiteit van het schetsen wordt door ontwerponderzoekers vaak in verband gebracht met creativiteit in het ontwerpproces. Vooral de vaagheid van schetsen lijkt namelijk uit te nodigen tot het geven van nieuwe betekenis aan de lijnen op het papier, hetgeen door ontwerponderzoekers 'herinterpretatie' wordt genoemd.

Zou het combineren van schetsen en ideegeneratietechnieken een betere ontwerpmethode op kunnen leveren? Immers, beide worden gezien als hulpmiddelen voor het stimuleren van creativiteit in het ontwerpen. Deze gedachte leidde tot het uitgangspunt van dit onderzoeksproject: het onderzoeken of het gebruik van schetsen als werkmedium in ideegeneratiesessies de toepasbaarheid van zulke sessies zou vergroten. Het leek waarschijnlijk dat ideegeneratietechnieken langzamerhand geaccepteerd zijn als ontwerpmethoden, zonder dat een kritische blik geworpen is op het gebruikte werkmedium. Indien dat het geval is, kan aanpassing van ideegeneratietechnieken aan de specifieke karakteristieken van de ontwerpdiscipline de toepasbaarheid binnen die discipline verbeteren.

Om structuur te bieden aan het zoekproces zijn twee inhoudelijke onderzoekservragen geformuleerd. De eerste vraag betreft het uitproberen van de effecten van verschillende manieren om schetsen in ideegeneratiesessies te introduceren:

Onderzoeks vraag 1: Hoe wordt het ideegeneratieproces van de groep beïnvloed door het op verschillende manieren introduceren van schetsen in ideegeneratiesessies?
Met de tweede vraag wordt geprobeerd een dieper begrip te krijgen van de manier waarop schetsen de structuur van het ideegeneratieproces veranderen:

**Onderzoeks vraag 2:** Wat zijn de verschillen in structuur tussen het ideegeneratieproces waarin schrijven gebruikt wordt als werkmiddel en het ideegeneratieproces waarin schetsen gebruikt wordt als werkmiddel?

Om deze inhoudelijke onderzoeks vragen te kunnen beantwoorden moest een onderzoeksmethode worden gevonden die inzicht geeft in de structuur van het ideegeneratieproces. Bestaande methoden die gebruikt worden om ideegeneratiesessies te onderzoeken vergelijken de verschillen in uitkomst tussen verschillende experimentele condities, meestal in termen van de kwantiteit en soms de kwaliteit van de gegenereerde ideeën. Deze resultaat-gerichte aanpak is populair vanwege zijn robuustheid en de bijbehorende academische geloofwaardigheid. Maar door het proces zelf te verwerpen als onderzoeksobject laat deze aanpak een rijke informatiebron onbenut. Als we geïnteresseerd zijn in het ideegeneratieproces is het informatiever om dat proces zelf te onderzoeken in plaats van de uitkomsten ervan. Dit heeft geleid tot een derde onderzoeks vraag gericht op het selecteren en/of ontwikkelen van een onderzoeksmethode die inzicht geeft in de structuur van ideegeneratieprocessen:

**Onderzoeks vraag 3:** Hoe kan het ideegeneratieproces zodanig beschreven worden dat verschillen in de structuur geanalyseerd kunnen worden, opdat de inhoudelijke vragen over de rol van schetsen in ideegeneratiesessies beantwoord kunnen worden?

Hieronder worden de conclusies van deze onderzoeks vragen samengevat. We beginnen met onderzoeks vraag nummer drie, omdat die de gebruikte onderzoeksmethode behandelt, hetgeen inzicht geeft in de manier waarop de data is geanalyseerd en hoe we tot de conclusies met betrekking tot de inhoudelijke vragen zijn gekomen.

**Hoe kan het ideegeneratieproces zodanig beschreven worden dat verschillen in de structuur geanalyseerd kunnen worden?**

In het veld van creativiteitsonderzoek zijn er geen methoden gevonden die inzicht geven in de structuur van het ideegeneratieproces. Daarom is er verder gezocht in het aanliggende veld van het ontwerponderzoek. In dit veld heeft Gabriela Goldschmidt een onderzoeks aanpak ontwikkeld die zich specifiek richt op de structuur van het ontwerpproces. Bij deze aanpak, door Goldschmidt ‘linkografie’ genoemd, worden verbindingen (‘links’) tussen ontwerpacties (‘moves’) geanalyseerd om patronen te onderzoeken in de structuur van het ontwerpproces.

In dit proefschrift is de linkografie methode verder ontwikkeld als methode om de structuur van ideegeneratieprocessen te bepalen. Verbindingen tussen ideeën zijn
bestudeerd in plaats van verbindingen tussen ontwerppacties. Ook zijn er een aantal indicatoren voor verbindingen tussen ideeën ontwikkeld. Vooral de rol van contextindicatoren (indicatoren die niet te maken hebben met het inhoudelijk verband tussen de ideeën) bleek belangrijk bij het bepalen of er al dan niet sprake was van een ‘link’ tussen twee ideeën. Een aanvullend onderzoek naar de soorten van contextindicatoren leverde negen categorieën op: 1) de tijdsinterval tussen de twee ideeën; 2) bestuderen van een eerder ideeën; 3) spontane fysieke reactie; 4) spontane verbale reactie; 5) zich terugtrekken om over een idee na te denken; 6) verband gelegd in de uitleg van een idee; 7) verband gelegd door toevoeging van een teken; 8) locatie van het idee op het papier; 9) gelijkenis in afbeelding. Met deze categorieën zouden kunnen helpen bij het ontwikkelen van betere richtlijnen voor het bepalen van verbindingen.

Om de structuur van ideegeneratiesessies te kunnen bestuderen moest de linkografie methode voldoen aan drie criteria. Allereerst moest de methode toegankelijk zijn. De methode moest een objectief beeld geven van het ideegeneratieproces en begrijpelijk zijn voor andere onderzoekers. Ten tweede moest de methode flexibel zijn. De gevonden linksystemen moesten zodanig worden geregistreerd zodat zij verscheidene analyses eenvoudig toe zouden laten. Als laatste moest de methode de resultaten uit verschillende sessies vergelijkbaar maken.

Om de systemen van verbindingen tussen ideeën toegankelijk en flexibel te maken zijn zij weergegeven in een matrixvorm. Dit maakte het eenvoudig om hier berekeningen mee te doen en analyses op uit te voeren. Daarnaast zijn er verschillende procesindicatoren ontwikkeld om een objectieve vergelijking tussen sessies toe te staan, te weten:

1. De linkdichtheid is een indicator voor de mate van integratie in het ideegeneratieproces. Een hoge linkdichtheid betekent dat de ideeën veel verbindingen hebben met eerdere ideeën.

2. De self-link index is de ratio van verbindingen die ontwerpers maken met hun eigen eerdere ideeën, ten opzichte van totale aantal verbindingen in de sessie. Samen met de linkdichtheid zegt de self-link index iets over de mate waarin de brainstormingrichtlijn van ‘bouw voort op elkaars ideeën’ wordt vervuld.

3. De link-type indices (supplementair, modificatie, tangentiële) geven de aard van de gemaakte verbindingen aan. Tangentiële verbindingen zijn een indicatie voor wilde sprongen in nieuwe richtingen, modificatie verbindingen geven directe variaties aan en supplementaire verbindingen zijn een indicatie voor kleine toevoegingen aan een bestaand idee.

4. De linkdichtheden voor de verschillende gebieden in het externe geheugen gaan specifiek in op de verschillende soorten interactie die mogelijk zijn met notaties van ideeën in het ‘extern geheugen’ van de groep (de flip-overs). Vier categorieën van verbindingen werden geïdentificeerd, die enerzijds verschil maakten tussen direct
gemaakte verbindingen en verbindingen met ideeën die veel eerder zijn gegenereerd), en anderzijds verschil maakten tussen zelflinks en interpersoonlijke links.

Linkografie is een methode in ontwikkeling. Veel vragen over de toepassing ervan zijn onbeantwoord gebleven, maar al met al is de methode een waardevol alternatief gebleken voor het traditionele experimentele onderzoek. Het construeren van linkmatrices is arbeidsintensief, maar daar staat tegenover dat het een goed inzicht verschaf in de verschillen in structuur van ideegeneratieprocessen.

Hoe wordt het ideegeneratieproces van de groep beïnvloed door het op verschillende manieren introduceren van schetsen in ideegeneratiesessies?

In de ontwerponderzoekliteratuur hebben we drie thema's geïdentificeerd met betrekking tot de manieren waarop schetsen kunnen bijdragen aan de creatieve processen van ontwerpteams:

1. Schetsen stimuleren een cyclus van herinterpretatie in het individuele denkproces. Terwijl een ontwerper schetst is hij of zij continue de gemaakte notaties op het papier aan het interpreteren en de consequenties daarvan aan het bekijken.


3. Schetsen stimuleren het gebruik van eerdere ideeën omdat zij de toegankelijkheid hiervan vergroten.

Om ook van toepassing te zijn op ideegeneratiesessies moest het ideeschetsproces compatibel zijn met het divergent ideegeneratieproces. Dit betekende in concreto dat het ideegeneratieproces niet mocht verslechteren als schetsen wordt gebruikt als werkmedium. Integendeel, het proces moest verbeteren. Om dit te verkennen zijn in de eerste empirische studie drie grafische variaties op brainstorming (waarin geschatst werd) toegepast in experimentele sessies. In een vierde sessie werd de bestaande, woordelijke, wijze van brainstormen toegepast als controle conditie. De variaties op brainstormen waarin het opschrijven van ideeën werd vervangen door schetsen scoorden in relatie tot normaal brainstormen substantieel lager op parameters die de richtlijnen van divergente ideegeneratie vertegenwoordigden. De volledig grafische variaties produceerden niet alleen minder ideeën, maar ook hun linkdichtheden waren lager, hetgeen betekent dat het proces minder goed geïntegreerd was. Op basis hiervan moest worden geconcludeerd dat de processen van ideeschetsen en divergent denken niet volledig compatibel zijn.

Hierdoor kon niet beoordeeld worden of de drie hierboven vermelde theoretische functies van schetsen in ontwerpgroepen ook gelden voor ideegeneratiesessies. Door
de resultaten van de tweede empirische studie echter opnieuw te analyseren konden de theoretische functies van schetsen toch verkend worden. Dit leverde enig bewijs op voor de eerste functie, namelijk dat schetsen een individuele interpretatieve cyclus bevordert. Zo was, voor de links met ideeën in het individueel-directe gebied van het extern geheugen, de tangentiële link-type index hoger dan gemiddeld. Voor de tweede functie, die suggereert dat schetsen ook herinterpretatie van elkaars ideeën stimuleert, werd geen bewijs gevonden. De derde functie, dat schetsen gebruik van eerdere ideeën stimuleren doordat zij de toegankelijkheid van deze ideeën verhogen, werd wel ondersteund. De linkdichtheden voor de afgelegene gebieden in het extern geheugen waren namelijk substantieel hoger voor de schetsconditie.

Wat zijn de verschillen in structuur tussen het ideegeneratieproces waarin schrijven gebruikt wordt als werkmedium en het ideegeneratieproces waarin schetsen gebruikt wordt als werkmedium? Omdat er incompatibiliteit tussen de processen van brainstorming en ideeschetsen was geconstateerd, is de richting van het onderzoek verlegd naar het verkrijgen van een dieper begrip van de verschillen tussen het grafische- en het woordelijke ideegeneratieproces. In de tweede empirische studie zijn twee ideegeneratietechnieken vergeleken die geacht werden representatief te zijn voor de werkmateriaal van schetsen en schrijven.

Brainstormen met post-its is geselecteerd als representatieve techniek voor woordelijke ideegeneratie en een variatie op ‘brainschetsen’ is ontwikkeld als representatieve techniek voor ideegeneratie met schetsen. De huidige manier van brainschetsen is geheel non-verbaal. Deelnemers schetsen individueel hun ideeën op flip-over vellen die op de muur zijn geplakt. Na een paar minuten veranderen de deelnemers van vel en gaan dan door met ideeschetsen. De eerder gemaakte ideeën van de andere ontwerpers worden als inspiratiebron gebruikt. Gewoonlijk zijn er een vijftal van zulke ideegeneratierondes. Echter, om representatief te zijn voor grafische groepstechnieken, moest er meer interactie zijn tussen de groepsleden in het ideegeneratieproces. Daarom is na iedere ideegeneratieronde een korte ronde geïntroduceerd waarin iedere ontwerper zijn ideeën kort toelichtte. Deze variant is ‘interactief brainschetsen’ genoemd. Een kleine pilot-studie gaf aan dat er, in vergelijking tot gewoon brainschetsen, bij interactief brainschetsen inderdaad meer op elkaars ideeën werd voortgebouwd.

Wat zijn dan de gevonden verschillen tussen de representatieve woordelijke techniek (brainstormen met post-its) en de representatieve grafische techniek (interactief brainschetsen)? Uit de link-type indices kan worden afgeleid dat bij het woordelijk ideegeneratieproces doorgaans een brede zoektocht naar nieuwe richtingen plaatsvindt (aangegeven door tangentiële verbindingen), aangevuld met korte verkenningen van sommige van deze richtingen (aangegeven door modificatie
verbindingen). Er is nauwelijks sprake van ideeontwikkeling (aangegeven door supplémentaire verbindingen). Dit is in overeenkomst met het bestaande beeld van het brainstormproces. Het grafische ideegeneratieproces lijkt eerdere ideeën meer te integreren in de latere ideeën. Ook is er meer ideeverfijning en ontwikkeling, terwijl dat niet ten koste gaat van de verscheidenheid in richtingen die worden verkend. De tangentiele link indexen voor brainschetsen en brainstormen zijn namelijk ongeveer even hoog. Grafische ideegeneratietechnieken lijken te leiden tot een ontwerpachtig ideegeneratieproces, dat bestaat uit een verkennen van nieuwe richtingen, gevolgd door het verkennen van een aantal van deze richtingen met ideeverfijning van een paar ideeën tot besluit.

Conclusies

De verschillende karakteristieken van het grafische en het woordelijke ideegeneratieproces suggereren dat zij verschillende toepassingen hebben. Woordelijke technieken lijken geschikter om de traditionele rol van ideegeneratietechnieken in het ontwerpen te vervullen, namelijk het genereren van een groot aantal en variëtè aan ontwerpideeën. Grafische technieken zijn geschikter wanneer een kleinere, maar beter ontwikkelde set ideeën gewenst is. Bij het opstarten van (team)ontwerpprojecten kan het bijvoorbeeld nuttig zijn om snel een simulatie te doen van het ontwerpproces dat gaat komen. Zo’n simulatie geeft de ontwerpers een gemeenschappelijk inzicht in de mogelijke ontwerprichtingen die in het project gevolgd zouden kunnen worden.

Daar de bestaande set van vier richtlijnen voor divergent denken direct verbonden zijn met het woordelijk ideegeneratieproces, is een alternatieve set van richtlijnen voorgesteld om het grafische ideegeneratieproces te ondersteunen. Deze richtlijnen benadrukken het belang van het maken van verbindingen met, en het interpreteren van, eerdere ideeën:

- **Bouw op elkaars ideeën.** Zoek in elkaars ideeën naar informatie die geïntegreerd kan worden in nieuwe ideeën. Interpreteer ideeën constructief. Interpreteer ideeën door suggesties of richtingen voor verdere ideegeneratie te zoeken, in plaats van het beoordelen van de waarde van ideeën als eindoplossingen.

- **Zorg voor beweging in de ideegeneratie.** Blijf niet enkele ideeën ontwikkelen of interpreteren. Probeer een cyclische beweging in de ideegeneratie te krijgen, waarin het genereren van ideeën en het interpreteren daarvan elkaar snel afwisselen.

- **Zoek naar wilde connecties, vooral bij het interpreteren van eigen ideeën.** Interpreteer en vertel ook de vreemdste ideeën. Die kunnen naar interessante nieuwe oplossingsrichtingen leiden.
Afsluitend kan gezegd worden dat het toepassen van schetsen in ideegeneratiesessies dus niet noodzakelijk een beter toepasbare ontwerpmethode oplevert. In plaats daarvan leidt het tot een structureel verschillend ideegeneratieproces. Dit grafisch ideegeneratieproces kan een waardevol alternatief bieden voor ontwerpers, met name wanneer wordt gelet op de gesuggereerde verschillen in toepassingsgebied tussen het woordelijk en het grafisch ideegeneratieproces.
References


(Eds.), Innovation: A cross-disciplinary perspective (pp. 205-232). Oslo: Norwegian University Press.


Curriculum Vitae

Remko van der Lugt (1968) works as an assistant professor in the department of Product Innovation and Management at the Sub-faculty of Industrial Design Engineering at the Delft University of Technology. His research focuses on the use of creative problem solving meetings in product design. He has published his research in *Design Studies* and in several international conference proceedings.

Next to his research activities, Remko has been involved with teaching design studio courses, courses in facilitating creative problem solving and product innovation management, and tutoring Master’s students. He also works as a freelance consultant in the field of creativity and innovation.

Remko received his Master’s degree in Naval Architecture from the Delft University of Technology (1993; annual best project award) and a Master’s Certificate in Creative Studies from the Center for Studies in Creativity at Buffalo State College, State University of New York (1995).

Before joining Delft University of Technology, Remko worked for an industrial design agency and as a free-lance creative problem solving facilitator. Between 1996-2000 he was board member of KreaNET, the Dutch network for promoters of creativity.