4

USING PRECEDENTS IN A DESIGN TASK

This chapter will bring the theoretical framework of the previous chapter into the realm of an actual design situation. The effects of providing designers with precedent designs as reference material while working on a design task, are studied in a design experiment. In this experiment two ways of organizing the provided precedents, random vs. typological, are compared. The results of the experiment show that the typological organization affords the transfer of design knowledge, as well as facilitates the breaking away by the designers of their pre-concepts (Pasman and Hennessey, 1999a).

Section 4.1 starts with a discussion and analysis of previous research, that has looked at the effects of providing designers with precedents as reference material in the design process. Combining the conclusions of this analysis with the assumptions brought forward in the theoretical framework, leads to the formulation of a set of hypotheses regarding the effects of organizing precedents into product types. An experiment was conducted to verify these hypotheses. The design and procedure of this experiment are described in sections 4.2 and 4.3, followed by a presentation of the results in section 4.4. The chapter finalizes with a discussion of these results and conclusions in section 4.5.

4.1 Using precedents in design

Precedents are commonly used in design education. By referring to existing solutions design teachers can show their students implications of possible design decisions, relationships between elements of a product, differences in form or meaning etc. Existing products are used as models in drawing courses, through which students' perceptional qualities are trained. Throughout their education, designers therefore are confronted with a large collection of possible design solutions, a process which continues when they start working in practice. Images of appealing products are collected from magazines and archived as reference material, products of competitors are reviewed to map the current solution space, product samples are displayed and studied as sources of knowledge and inspiration etc. (Asby and Johnson, 2002)

This ubiquitous presence of examples in the design process has initiated a number a studies in design methodology, aimed at acquiring a better understanding of the effects these examples have on the designer's reasoning process, as well as on the results of this reasoning process. The results of these studies will now be reviewed regarding their possible implications for the theoretical framework of chapter 3.

Fixation

Although the use of examples as reference material in design is widely acknowledged, the discussion of their role and influence in the design process has been primarily based in anecdotic descriptions or personal experiences. Theories in the field of information processing suggest that in order to come up with innovative designs, the designer needs the cognitive ability to recognize and externalize the knowledge that is embedded in existing solutions (Oxman, 1997). However, most designers are not trained in this ability, making it hard for them to break away from their preconceived ideas.

Jansson and Smith (1991) were the first to apply an experimental approach to the subject. They started their work from the assumption that examples of existing solutions might act as possible barriers in the idea generation, blocking the development of new and innovative solutions. They argue that providing designers with a pictorial representation of an object, depicting a physical realization of a solution to the problem at hand, would result in a premature and even counterproductive commitment to this solution. They define this effect as 'design fixation', being the blind adherence to a set of ideas or concepts limiting the output of the design process. In a series of experiments they tested their assumptions. All experiments used the same, relatively simple design. Two groups of subjects, all engineering design students, were given a design problem, for which they were asked to generate as many solutions as possible. The experimental group was given a written statement of the problem together with a picture of an example solution, while the control group received only the written statement. The subjects were then given one hour to come up with as many solutions as they liked. All of these solutions were then scored for presence or absence of the characteristic features of the example solution, which were previously determined by the experimenters. The number of features in common between example solution and designed solution, was then taken as a measure for the occurrence of fixation. The experiments repeatedly demonstrated the existence of a fixation effect, the solutions which were developed by the experimental group reflecting to a significantly greater extent those features being present in the provided example(s), even if these features included obvious flaws with respect to the given design task.

Purcell and Gero (1996) extended the work of Jansson and Smith, using mechanical engineers as well as industrial designers as subjects in their experiments. Replicating the experimental design of their predecessors, they explored the role of design discipline and expertise in the design fixation effect. In none of their experimental conditions did they find a fixation effect for the group of industrial designers, this in contrast to the group of mechanical engineers, which clearly showed signs of fixation in their design behavior. Purcell and Gero contribute this difference to the nature of the educational program in industrial design, which strongly encourages the development of innovative, distinct solutions. As a consequence, industrial designers would be fixated on 'being different', thus considering the existing solutions that were presented to them as representatives of the 'old and known', from which they had to stay away as far as possible. In their analysis, however, Purcell and Gero only used aspects which refer to the technical principle and functional details of the produced designs. The example which they have labeled as 'innovative' is a design, which embodies a technical principle that has been rated by mechanical engineers as being innovative. Thus aspects relating to form and meaning, which are essential in the domain of industrial design, were not involved in the analysis.

Prior design knowledge

Purcell and Gero also suggested that familiarity with a presented example could be the predominant factor in the occurrence of a fixation effect. They stated that especially novice designers, who have not build up a large body of domain-specific knowledge, would rely on their general, everyday knowledge, as most strongly represented by the most familiar example. Indeed, in one of their experiments they found that a fixation effect only occurred with an example that was familiar to the subjects. A similar result was found by Christiaans and Van Andel (1993) in their study of the effects of examples on the use of knowledge in a student design activity. Having to design a hand-driven go-cart for children, the group of students which was presented with a familiar example of such a go-cart, if only described verbally, did reproduce in their designs a number of characteristics of the example. The results of both studies suggest that prior knowledge of existing solutions can have a profound effect on the results of this design task. In their later experiments Purcell and Gero avoided the issue of prior knowledge by selecting design problems with which the subjects most likely would not have had any experience at all. Although this can be justified from an experimental point of view, such situations will hardly ever occur in design practice.

Designers do not enter a new design situation as 'tubula rasas'. Through education and practice they have acquired a vast repertoire of design solutions, which they will carry over the design task at hand. These solutions construct the designer's preconceived ideas regarding function, form and meaning of a product, and the mutual relationships between these aspects. Darke (1979) has stated that these preconceptions seem to act as a points of departure in the development of a design concept. When confronted with a new design situation, the designer imposes images of possible solutions on to it. These images provide a means for the designer to analyze and structure the design situation, thus directing the actual development of the product form.

Since the focus of this thesis is on the role of products as 'Gestalts', which can be grouped in product types, the attention will be concentrated on the pre-conceptual image of such a product type, respectively the mental representation that the designer has stored in memory for the type in question. This representation will be constructed around the most typical instances characterizing the type, thus reflecting its central tendency. This representation will be referred to as a 'pre-concept' in the rest of this thesis.

The construct of a pre-concept has important implications for the formation of new concepts. Basic-level categories have been identified here as possible catalyzing elements in this process, since their level of knowledge organization affords projection to the more general. super-ordinate level or the more specific, sub-ordinate level. Referring to the characteristics of a basic-level category pre-concepts can now be defined as a conceptual structures, which organize a designer's existing, pre-situational design knowledge regarding a products' function, form and meaning on a basic-level. So, if designers enter a new design situation equipped with knowledge of existing solutions, what role does this knowledge play in the new situation and could it possibly produce a counter-productive effect similar to the fixation effect defined by Jansson and Smith? And in what way could this effect then be reduced?

Although pre-concepts, by means of their basic-level structure, are powerful points of departure in the generation and exploration of new solutions, their high degree of typicality might also have a restricting effect on the designer, similar to the effect of familiar examples. If a designer is unable to leave the basic-level of the pre-concept, because it offers such an 'obvious' solution to the problem at hand or because a rich structure of design knowledge has not been developed yet, it will be highly likely that the result of the design process will be at most a modification of the initial pre-concept. No displacement of concepts has taken place then, since a new instance has merely been added to the typical instances making up the pre-concept. Thus the pre-concept might act as a barrier in the design process, blocking the ideation process of the designer.

Throughout the rest of this thesis the fixation effect will therefore be operationalized in a way different from Jansson and Smith. Fixation in our framework refers to a designer's adherence to his or her preconceived ideas, as represented by the pre-concept. The difference between the pre-concept and the result of a corresponding design task, will thus be taken as a measure to determine the occurrence of fixation.

4.2 Designing the experiment

Hypotheses

Previously a framework has been constructed for describing precedents in terms of design knowledge regarding function, form and meaning. This knowledge would be reflected in the precedents' salient 'Gestalt' determining characteristics of the precedents' appearances regarding these three aspects. It has been argued that grouping together a collection of product instances on their typicality, will lead to the formation of product types. In these types the product-specific knowledge of the instances would be organized on a problem-independent level, enabling a transfer of the embedded design knowledge to new situations. Will providing designers with precedents organized by type indeed result in new form concepts, whose appearances reflect the same characteristics that make up these types? And will product types by means of their general nature indeed encourage designers to break away from their pre-concepts, resulting in more innovative ideas? Or will they have just the opposite effect, seducing designers to what is already existing?

With respect to the effects of providing design knowledge organized in product types, the following hypothesis thus is formulated:

Hypothesis 4.1, regarding the effect of product types:

Providing designers in a design situation with reference material consisting of precedents organized in types, as opposed to individual instances, will result in design concepts which reflect in their appearance to a greater extent the 'Gestalt' determining features of the provided types.

With respect to the fixation effect induced by the pre-concept, the following hypothesis is formulated:

Hypothesis 4.2, regarding the effect of fixating on the pre-concept

Providing designers in a design situation with reference material consisting of precedents organized in types, as opposed to individual instances, will result in *design concepts which reflect in their appearance to a lesser extent the 'Gestalt' determining features of their corresponding pre-concepts, thus reducing the fixation effect.*

Experimental design

The goal of the experiment was the verification of these two hypotheses. To achieve this in one setting it was decided to use the design depicted in figure 4.1.

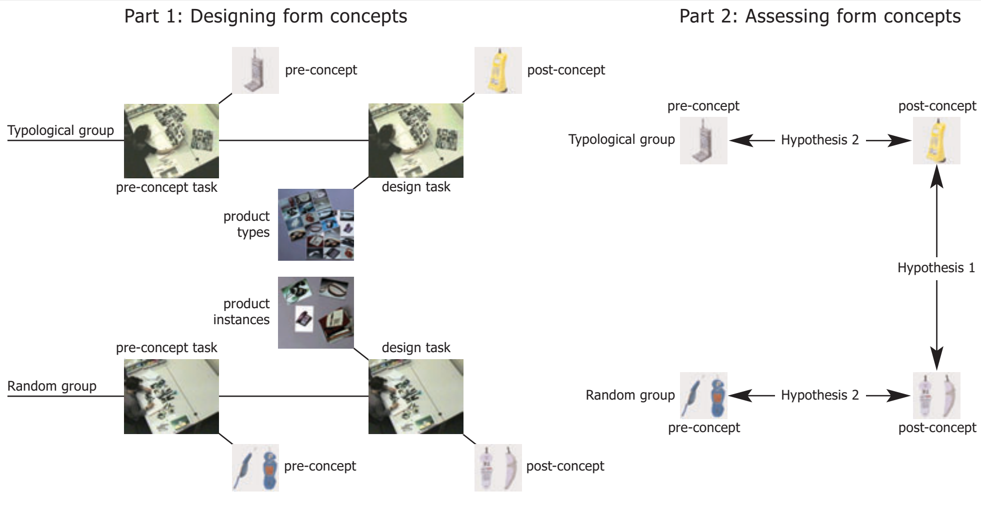

Figure 4.1 Design of the experiment in two parts: Designing form concepts, and Assessing form concepts.

The experiment consisted of two parts: 1. Designing form concepts, and 2. Assessing form concepts. At the start of part 1 the subjects, all Industrial Design Engineering students, were requested to externalize their preconceived ideas of the appearance of a given product, resulting in a visual representation of their pre-concept of the product (pre-concept task). Then they were given the task to design new form concepts of this product for a specific target group (design task). At the start of this design task they were provided with photographs of precedents of the product, which they could refer to while designing. Half of the subjects (the Typological group) was given photographs of the precedents organized in product types, while the other half (the Random group) was provided with the same set of photographs in one, unorganized stack of product instances. All subjects had to produce one final post-concept as the result of their design work. In part 2, a different body of subjects had to assess the pre-concepts and post-concepts of both groups. Comparison of the post-concepts of both groups then provided a measure for Hypothesis 4.1, while comparing for both groups the differences between post-concept and pre-concepts enabled the verification of Hypothesis 4.2.

4.3 Part 1: Designing form concepts

The choice of the product

As a first step in the design of the experiment the product to be designed was selected. Since the domain of this thesis is the form-creation phase of the product design process, it was decided that the product to be designed should be a fairly small, compact and not too complicated object. Starting from a given solution principle and resulting in a form concept, its design should represent a task typical for the form creation phase. Thus a mobile telephone was selected as a suitable product. It is a small, hand-held object, which is kept close to the body when operated and within reach of the body when in the standby-mode. Thus it becomes part of the owner's image, which introduces a set of behaviors, preferences and cultural styles, making it very well suited for a form exploration task. Although at the time of the experiment (1994) the mobile telephone was not the ubiquitous object it is today, it was already common enough to expect designers to have preconceptions of it.

The pre-concept task

To acquire an indication of the pre-concept designers might use as a starting point in the design task, a representation of this pre-concept should be obtained before the task actually starts. To allow comparison with concepts that are produced as a final result of this design task, the notion of a pre-concept needs to be operationalized into a similar form. Thus the following task has been formulated, which will precede the actual design task:

Draw from memory, in perspective and color, a mobile telephone. Make use of fine liners and markers and limit the size of your drawing to about half of an A4 . You have 15 minutes to complete this task.

The result of this task will now be labeled as the subject's pre-concept. The limited period of time allotted to the subjects for representing this pre-concept, the level of detail required of this representation, as well as the unfamiliar situation of the experiment, impose a set of restrictions leaving little room for a thorough exploration of the whole solution space. The need for a visual non-linguistic representation directs the attention to the product's appearance as a 'whole', which is in accordance with the rules of a typology. Under these conditions it is expected that the subjects will externalize their most typical representation of the product, reflecting the most salient 'Gestalt' features, that determine its appearance.

The design task

The choice and precise formulation of the design task is a crucial element in the design of the experiment. Its description in linguistic terms, as laid down in the design brief, heavily structures the design situation, determining for an essential part the selection of relevant product types for displacement. The following design brief was formulated:

The client

Hands-On is a beginning manufacturer of telephones, who wants to put its first product on the market within one year. In order to increase the chances of a successful introduction, the existing market has been thoroughly analyzed. Extensive marketing research has led to the conclusion that the ever increasing number of female executives is a target group, that is insufficiently served with the telephones which are currently on the market.
Based on this the management of Hands-On decides to work on a line of products, specifically for this target group, that has to clearly distinguish itself from the current market supply.

The brief

You are hired by Hands-On as a free-lance designer to design a mobile telephone, specifically for a female executive. Tomorrow you have a meeting with the management of Hands-On, in which you will have to present your first concept. You will have to provide the members of the management team with a realistic impression of the generated concept regarding form and color, as well as their use by the target group.

You have 90 minutes to complete this task.

Dorst (1997) lists a number of factors to be considered in setting up a design task for research purposes. These will now be presented, to explain the reasoning process leading to the final formulation of the design brief.

- **Challenging**

By selecting female executives as the target group for the new product, bringing with it a different set of preferences, demands, behaviors etc., we expected our subjects to be challenged to contrast in their own concepts, the (at the time of the experiment) dominant image of rather masculine, robust and formal mobile telephones. The specific requirement that the new concept should "clearly distinguish itself from the current market supply" should encourage the subjects to come up with something original and surprising.

- **Realistic**

The conditions set by the task (written design brief, time pressure, concept drawings to present the ideas) are typical for the kind of projects in a small design office. Incorporating into the setting the management of a (fictitious) company, which will act as a sounding board for the developed concepts, further enhances its level of reality.

- **Appropriate for the subjects**

All subjects were senior students of Industrial Design Engineering. Throughout their study they have had many assignments similar to the experimental one. They have learned to analyze a problem, identify the important factors at stake, draw up a list of requirements, translate these into physical concepts and evaluate these on their suitability for the given situation. In this process they apply and integrate knowledge from various sources, such as design magazines, product catalogues, manuals etc., and domains, such as marketing, ergonomics, psychology etc. They also have had extensive training in drawing- and presentation techniques and thus possess sufficient drawings skills to produce the concept drawing at the end of the task. Finally, as future professional industrial designers the subjects fit into the focus group of this thesis.

- **Not too large**

  The product to be designed is a fairly small, compact and not too complicated object. Starting from a given solution principle and resulting in a form concept, it represents a task typical for the form creation process.

- **Feasible in the time available**

  The time span allotted to the subjects was 90 minutes. In their educational program the subjects have often been confronted with deadlines, although probably not on such a short notice as in this case. Making the deliverable of the task "a realistic impression of the generated concept regarding form and color, as well as its use by the target group" will direct the subjects to concentrate their design efforts on defining the product's overall appearance, thus putting aside details concerning technology and manufacturing.

- **Within the sphere of knowledge of the researchers**

  To identify the issues involved in the design task and to be able to answer questions during the experiment, it is important that the researches have enough knowledge on the various aspects of the design situation. Being both researchers and educators at the Faculty of Industrial Design Engineering they are confronted almost on a daily basis with the kind of problems similar to the one of the experiment.

Stimulus material

During the design task the subjects can draw reference to images of existing telephones. The Typological group receives these images organized into product types, while the Random group receives the same images without any organization at all. In constructing this stimulus material the following steps were taken:

1 The selection of the relevant product types

According to the framework, the selection of relevant product types, affording displacement of the knowledge they embody to a new design situation, is induced by the conceptual structure of this situation. The main element providing this structure is the linguistic description of the situation by means of the design brief. From this brief, the concepts of "mobile telephone", "female" and "executive" were selected by the experimenters as concepts likely to be picked up by the subjects.

An analysis of mobile telephones on the market at the time of the experiment showed a strong dominance of compact, robust and symmetric shapes, in dark and formal colors and with a symmetrical placement of elements, like buttons and a display, on the body. This arrangement probably was a consequence of the way in which these products were marketed, aiming primarily at the high-end group of businessmen. By incorporating telephones that contrast this image into the stimulus material, it was hoped to initiate the generation and development of original form concepts. However, it was also decided to incorporate telephones that confirm the current image, to identify whether the provided precedents could also act as fortifying examples.

A final restriction concerns selecting types from all three levels of knowledge organization which have been previously defined: the basic-level, which implies the most economical level of organization; the higher-order, more general super-ordinate level; and the lower-order, more specific sub-ordinate level.

The following five product types were therefore identified as relevant for the design task:

- **“Asymmetric”**

  Organizing design knowledge on a super-ordinate level regarding the ordering and placement of the elements of the product;

- **“Elegant”**

  Organizing design knowledge on a super-ordinate level regarding the articulation of the proportions of the overall appearance of the product;

- **"Formal"**

  Organizing design knowledge on a sub-ordinate level regarding the socio-cultural context in which the product is used;

- **"Feminine"**

  Organizing design knowledge on a sub-ordinate level regarding the behavior that is expressed while using the product;

- **"Typical "**

  Organizing design knowledge on a basic-level, regarding the spatial schema underlying the total class of mobile telephones.

Thus, the types “Asymmetric”, “Elegant” and “Feminine” are in line with the context of the design task at hand, while the types “Formal” and “Typical” are in contrast.

2 The formation of the product types

The five product types were then formed according to the following procedure: From the archives of our department 69 photographs of existing telephones were selected, representing a variety in function, form and use. These photographs (10 x 15 cm) were then assessed by a panel of 6 senior industrial design engineering students (3 male, 3 female) on the following bi-polar scales: Asymmetrical-Symmetrical; Elegant-Robust; Formal-Informal; Feminine-Masculine.

The members of the panel were asked for each scale to divide the total group of 69 photographs into 5 smaller groups. Table 4.1 shows intraclass correlations, which were calculated for each scale to determine the degree of agreement between the panel members. They reveal that for each of the four scales the interrater reliability was significantly high for $p < 0.05$.

Based on the results of this assessment 4 product types were assembled out of those 12 products that were rated highest on the features Asymmetrical,

Table 4.1 Degree of agreement between the members of the panel

Scale	Intraclass Correlation Coefficient
Asymmetrical-Symmetrical	.5575*
Elegant-Robust	.5408*
Formal-Informal	.4944*
Feminine-Masculine	.4607*

Elegant, Formal and Feminine. The fifth product type, Typical, consisting of 12 photographs of only mobile telephones, was assembled by the experimenters. Within a product type the images were randomly organized. Because some products appeared in more than one type, the total set consisted of 46 different telephones. Figures 4.2 to 4.6 show the five resulting product types.

Figure 4.2 "Elegant", organizing design knowledge on a super-ordinate level regarding the articulation of the proportions of the overall appearance of the product

Figure 4.3 "Feminine", organizing design knowledge on a sub-ordinate level regarding the behavior that is expressed while using the product

Figure 4.4 "Asymmetrical, organizing design knowledge on a super-ordinate level regarding the ordering and placement of the elements of the product.

Figure 4.5 "Formal", organizing design know-ledge on a sub-ordinate level regarding the socio-cultural context in which the product is used.

Figure 4.6 "Typical", organizing design know-ledge on a basic-level, regarding the spatial schema underlying the total class of mobile telephones.

Subjects

16 senior Industrial Design Engineering students (8 male, 8 female) participated in the experiment. They were randomly assigned to either the Typological group (experimental) or the Random group (control), resulting in two groups of 8 subjects each. Both groups were then compared with respect to gender, years of study and their grades for drawing and design courses. This procedure was repeated until both groups were equally balanced. Each subject performed the experiment individually. The subjects were paid a small amount for their participation, which took 2 hours each.

Procedure

At the start of the experiment each subject was welcomed by the experimenter. After a brief explanation of the procedure, the pre-concept task was presented to the subject. After 15 minutes the result of this task, a sketch of the subject’s pre-concept, was taken from them. During the rest of the experiment they were not allowed to look at their pre-concept anymore. The actual design brief was then presented to the subject. After reading the brief, the subjects were provided with the stimulus material: the subjects in the Typological group receiving the five product types, the subjects in the Random group receiving the unorganized stack of photographs. The main design session of 90 minutes then started. After 75 minutes the subjects were reminded that they had to present a sketch of their final concept in 15 minutes. During the experiment a subject was seated at a large table with sufficient space to comfortably work. To perform both tasks, the subject could make use of a large collection of sketching and drawing tools, such as pencils, markers, rulers, sketching and tracing paper etc. The experimenter was seated at the same table, to be able to answer possible questions and to keep track of the time.

4.4 Part 2: Assessing form concepts

In this second part of the experiment the produced pre-concepts and post-concepts of both groups were compared to determine any differences between both conditions. To be able to make various kinds of comparisons it was decided to conduct a paired-comparison test. In this test each concept was paired with each of the other 31 concepts for each of the five types used in part 1. Thus the subjects who acted as judges were, each time, presented two concepts, of which they had to select the one that in their opinion best represented the given criterion. Figure 4.7 shows an example of such an assessment.

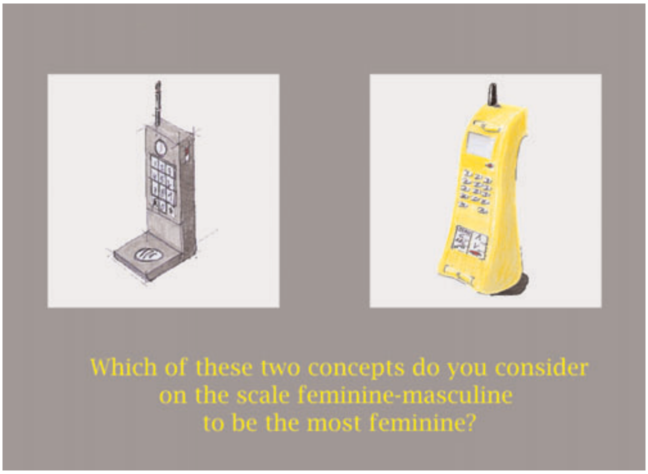

Figure 4.7 Example of a paired comparison between two concepts on the scale feminine-masculin.

Thus for each concept a score is obtained for each of the five types. The total group of 32 concepts can be divided into four sets of 8 concepts each, as shown in table 4.2.

Table 4.2 Division of the total number of concepts into four sets.

	Pre-concepts	Post-concepts
Random	R,pre	R,post
Typological	T,pre	T,post

The dependent variable $Y_{a:b}$ is the number of times concept A is preferred above concept B. Adding the scores of all 8 concepts in a set relative to all 8 concepts in one of the other sets makes comparisons between sets possible. E.g. $Y_{R,pre:T,pre}$ is the number of times the pre-concepts of the Random group are preferred above the pre-concepts of the Typological group. Thus the scores of all of the 4 sets could be compared to each other.

Subjects

Sixteen senior industrial design engineering students (8 male and 8 female) participated in the test. Each subject performed the task individually. They were paid a small amount for their participation.

Procedure

All 32 concepts were first put into digital format by scanning them into the computer at a resolution of 150 dots per inch. To minimize the differences between the concepts that were not relevant for their comparison, each concept was depicted on the same neutral-gray background. Using Macromedia Director™ an application was written with which the task was performed. The application was running on an Apple Macintosh 660 AV with a 15 inch RGB-monitor, which was set to a resolution of 640 x 480 and thousands of colors.

After a brief introduction, in which the judges were given instructions, they had to complete a short training session of 6 comparisons in order to get used to the assessment method. On the screen two concepts were presented side-by-side, together with a question of the following kind: "Which of these two concepts do you consider on the scale feminine-masculine to be the most feminine". It was decided to present the scale with the juxtaposed feature to provide each of the judges the same frame of reference on which to base his or her decisions on. The judges were asked to base their discussion on their first impression of the concepts' overall appearances rather than on a thorough analysis of their functional or technical details. By clicking on the concept of their choice their preference was recorded, after which the next pair of concepts was presented to them.

The training session was followed by the actual assessment. For each of the five types (Asymmetrical, Elegant, Formal, Typical and Feminine) all of the possible 496 comparisons had to be made before the same procedure was repeated with the next type. The order of the types was balanced over the sixteen judges. The order of the concepts, as well as their place on the screen (right or left) was randomly varied.

4.5 Results

Reliability

To assess the reliability of the judges' rating, again intraclass correlations were calculated for each scale. Comparison with table 4.1 shows a higher degree of agreement for all 4 scales. This is probably due to the more equal procedure of a paired-comparison, in which each subject has to assess exactly the same set of comparisons, as well as to the narrow focus formulated in the given design brief.

Table 4.2 Degree of agreement between the judges for the five bi-polar scales

Scale	Intraclass Correlation Coefficient
Asymmetrical-Symmetrical	.5616*
Elegant-Robust	.6453*
Formal-Informal	.7638*
Typical-Atypical	.5216*
Feminine-Masculine	.6886*

The effect of the product types.

Hypothesis 4.1 predicted that the post-concepts of the Typological group would reflect, in their appearance, more of the features of the provided product types as compared to the post-concepts of the Random group. Thus for the score Y the following equations are formulated:

Table 4.3 Hypotheses for post-concepts, Random vs. Typological

H0	H1
$Y_{Tpost:Rpost} \leq Y_{Rpost:Tpost}$	$Y_{Tpost:Rpost} > Y_{Rpost:Tpost}$
Asymmetrical, Elegant, Informal, Atypical, Feminine	Asymmetrical, Elegant, Informal, Atypical, Feminine

N.B. To keep all scales in the direction as was to be expected based on the design brief, it was decided for presentation purposes to use Informal and Atypical instead of Formal and Typical.

To analyze the differences between both groups the binomial test is chosen because the data is in two discrete categories and the design is of the one-sample type. In the following table the results for the post-concepts of both

Table 4.4 Number of times a post-concept has been preferred, Random vs. Typological

Scale	$Y_{T,Post: R,Post}$	$Y_{R, Post:T,Post}$	z	p
Asymmetrical	581	443	4.28	< 0.0001
Elegant	556	468	2.72	0.033
Informal	653	371	8.78	< 0.0001
Atypical	581	443	4.28	< 0.0001
Feminine	574	450	3.84	0.0006

groups are presented for the five types, together with the z value and the resulting p value.

Figure 4.8 Post-concepts of the Random groups vs. post-concepts of the Typological group

For $\alpha = 0.05$ the difference between both groups is significant and in the predicted direction for all five features. However, it needs to be determined if these differences were not already present in the pre-concepts of both groups, which were made before the experimental condition was introduced, in order to ascribe this effect to the organization of the presented product types. Therefore the scores for the pre-concepts of both groups are compared, the results of which are presented in table 4.5.

Table 4.4 Number of times a pre-concept has been preferred, Random vs. Typological

Scale	$Y_{T,Pre: R,Pre}$	$Y_{R, Pre:T,Pre}$	z	p
Asymmetrical	405	619	-6.66	< 0.0001
Elegant	479	545	-2.03	0.0217
Informal	239	785	-17.03	< 0.0001
Atypical	269	755	-15.16	< 0.0001
Feminine	228	796	-17.72	< 0.0001

To our surprise, significant differences were found for each of the five types. But since the direction of them all run opposed to our hypothesis, these differences in pre-concepts do not provide for an alternative explanation for the significant

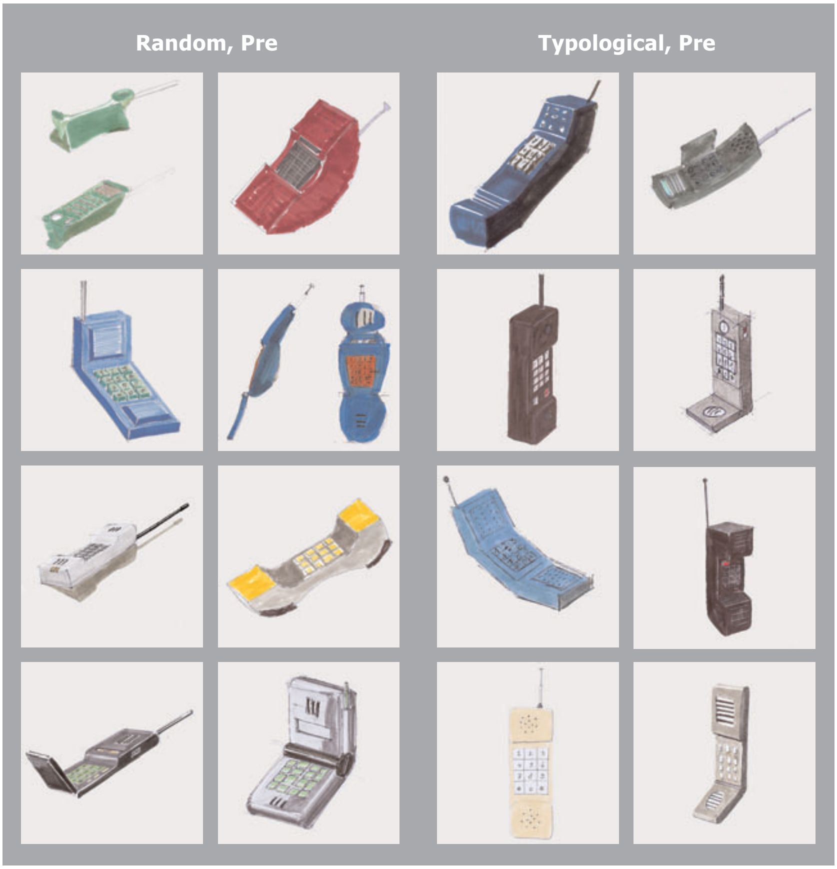

Figure 4.9 Pre-concepts of the Random groups vs. pre-concepts of the Typological group

differences found for the post-concepts. One could even argue that it strengthens our findings because the improvement was gained against unequal odds.

Again for α = 0.05 the differences between both groups are significant, but, surprisingly, the direction is opposed to those found for the post-concepts.

The effect of fixation on the pre-concept

Hypothesis 4.2 predicted that the difference between pre-concept and post-concept would be greater for the Typological group due to the more generic character of the knowledge organization of the product types. To determine these differences the score Δ is introduced, which is obtained in the following way: First the number of times a post-concept of a subject has been preferred above its pre-concept is subtracted with the opposite comparison. The scores of all 8 subject in a group then add up to the score Δ. Thus the following equations can be listed:

Table 4.6 Hypotheses for Δ, Typological vs. Random

H0	H1
$\Delta_T \leq \Delta_R$	$\Delta_T > \Delta_R$
Asymmetrical, Elegant, Informal, Atypical, Feminine	Asymmetrical, Elegant, Informal, Atypical, Feminine

To compare the differences in development between the two groups, the Fisher exact probability test for 2 x 2 tables is used. This test determines whether two independent groups differ in their proportion with which they fall into two mutually exclusive categories. In this case the categories are 1) post-concept preferred above pre-concept and 2) pre-concept preferred above post-concept.

In table 4.7 the obtained frequencies are presented, together with the resulting probability.

Table 4.7 Δ(post-concepts / pre-concepts), Random vs. Typological Scale

Scale	Δ_T	Δ_R	p
Asymmetrical	46	38	.6915
Elegant	50	58	.6793
Informal	90	-12	< 0.0001
Atypical	64	-8	< 0.0001
Feminine	94	36	< 0.0001

Here for Informal, Atypical and Feminine the differences are significant and in the predicted direction. For Asymmetrical the direction is still as predicted, while for Elegant the direction of the difference is opposed to what was expected, however both not significantly.

The effects of the design situation

Although formally not a condition in the experiment (a third group receiving no precedents at all had to be added), it is nevertheless interesting to look at the effects the design situation, as stated in the design brief, has on the outcomes of the experiment. Since the design brief introduced a specific, rather unusual target group, as well as the need to make the new concept clearly distinguishable from the current market supply, we should expect our subjects to distinguish themselves from their preconceived ideas as externalized in their pre-concepts. If the five product types, which we have deducted from the design brief, are indeed relevant to the given situation, for both groups the post-concepts, as compared to their corresponding pre-concepts, should reflect in their appearances to a greater extent the features of the product types. So, although we can not subscribe this effect entirely to the design situation, it gives us at least an indication of the validity of the selected product types. Thus the following table can be drawn up:

Table 4.8 Hypotheses for pre-concepts vs. post-concepts

H0	H1
$Y_{R,post:R,pre} \leq Y_{R,pre:R,post}$ Asymmetrical, Elegant, Informal, Atypical, Feminine	$Y_{R,post:R,pre} > Y_{R,pre:R,post}$ Asymmetrical, Elegant, Informal, Atypical, Feminine
$Y_{T,post:T,pre} \leq Y_{T,pre:T,post}$ Asymmetrical, Elegant, Informal, Atypical, Feminine	$Y_{T,post:T,pre} > Y_{T,pre:T,post}$ Asymmetrical, Elegant, Informal, Atypical, Feminine

For this comparison only the matching of a pre-concept with its corresponding post-concept will have to be considered. Table 4.9 presents the results of the Random group, while table 4.10 shows the corresponding numbers for the Typological group.

Table 4.9 Random group, pre-concepts vs. post-concepts

Scale	$Y_{R,Pre: R,Post}$	$Y_{R, Post:R,Pre}$	z	p
Asymmetrical	45	83	-3.27	0.0006
Elegant	35	93	-5.04	< 0.0001
Informal	70	58	0.97	0.1660
Atypical	68	60	0.62	0.2709
Feminine	46	82	-3.09	0.0010

Figure 4.10 Random group, pre-concepts vs. post-concepts

Table 4.10 Typological group, pre-concepts vs. post-concepts

Scale	$Y_{T,Pre: T,Post}$	$Y_{T, Post:T,Pre}$	z	p
Asymmetrical	26	102	-6.63	< 0.0001
Elegant	39	89	-4.33	< 0.0001
Informal	19	109	-7.87	< 0.0001
Atypical	32	96	-5.57	< 0.0001
Feminine	17	111	-8.22	< 0.0001

Figure 4.11 Typological group, pre-concepts vs. post-concepts

For the Typological group all differences were significant for $\alpha = 0.05$ and in the expected direction. For the Random group the differences for Informal and Atypical are not significant. Moreover the direction of these differences are opposed to what was expected on the design brief.

4.6 Conclusions

Figure 4.12 shows for each of the five scales the scores of R_{post}, T_{pre} and T_{post} relative to R_{pre}. A significant effect was found for both hypothesis 4.1 and 4.2.

Hypothesis 4.1 predicted that providing designers with typologically organized examples would results in design concepts, which would reflect in their appearances more of the design features that make up for the typological organization. Thus the post-concepts of the Typological group were expected to be more feminine, asymmetrical, elegant as well as more formal and typical than the post-concepts of the Random group. For the three types (Asymmetrical, Elegant, Feminine) that were in line with the design brief, this is indeed the case. But for the two types (Formal, Typical), that were in contrast with the design brief, the effect is just opposite: the post-concepts of the Typological group were assessed as being less formal and typical than the post-concepts of the Random group. The designers followed the brief, not the examples.

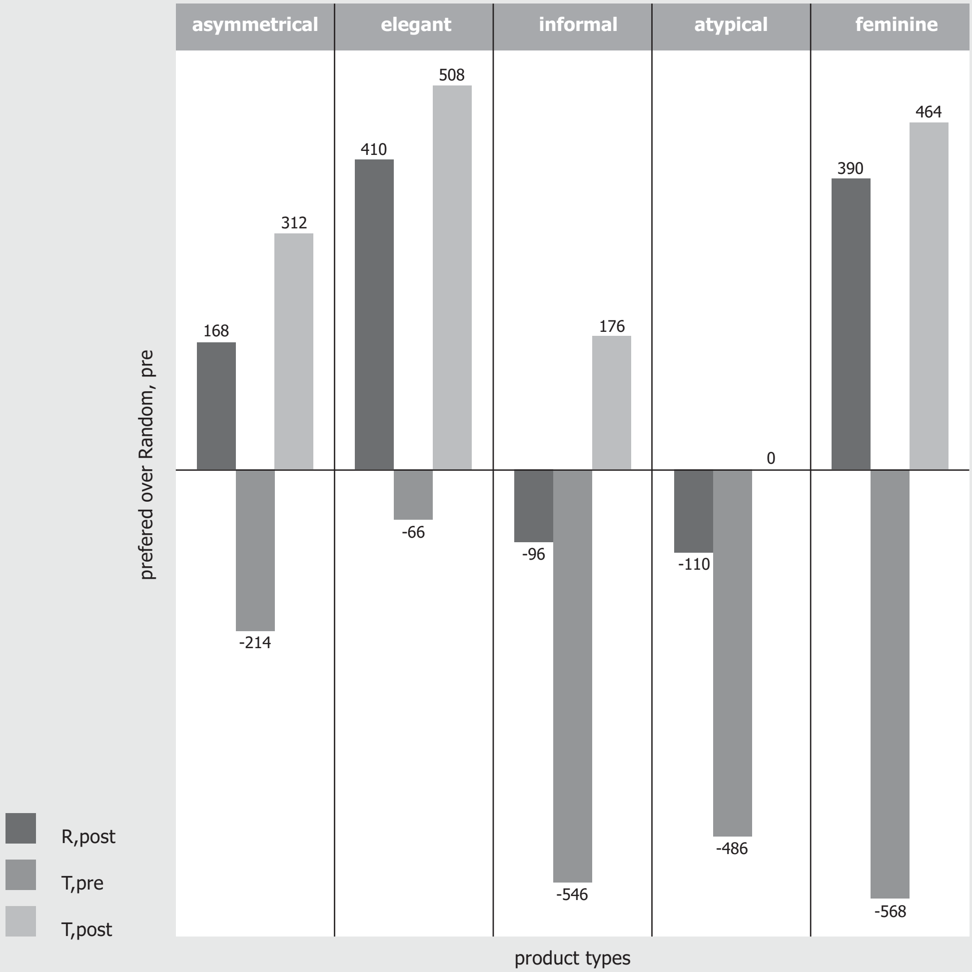

Figure 4.12 Number of times a concept has been preferred over R,pre concepts

This might suggest that a typological organization of design knowledge indeed facilitates the transfer and application of this knowledge into new design situations, but that its effect can be twofold:

- When a product type is in line with the given design situation, the precedents that make up for the product type are used as confirming examples, forming a 'positive' frame of reference for the generation and development of new form concepts.
- When a product type is in contrast with the given design situation, the precedents that make up for the product type are used as contrasting examples, forming a 'negative' frame of reference for the generation and development of new form concepts. Organizing such examples into a product type would emphasize their contrast to the current design situation to such an extent, that a transfer to this situation of their negative features, as was found in the experiments of Jansson and Smith, does not take place.

Figure 4.12 also shows an unexpected difference between the pre-concepts of both groups. Because the subjects were randomly assigned to one of the groups, and had not yet received different treatments when they made their pre-concepts, one would expect to find no differences between R_{pre} and T_{pre}. But the differences are significant, even large. It is unclear why these differences occurred. Both groups were equally balanced with regard to design and presentation qualities, so they can not be attributed to differences in design capabilities. Fortunately for our hypothesis, though, the differences consistently work against it: the subjects in the Typological group had to bridge a larger distance from their pre-concepts to post-concepts that were in line with the design brief, but they did do so. For example, for "Asymmetrical" the difference tested between the post-concepts of both groups was 312 - 168 = 144, but the increase that the subjects achieved between pre-concept and post-concept was 168 - 0 = 168 for the Random group, but 312 - 214 = 526 for the Typological group.

Regarding hypothesis 4.2, the subjects in the Typological group indeed show much more development from pre-concept to post-concept, in the direction that was expected considering the design brief. This indicates that they were better able to break away from their preconceived ideas than the subjects in the Random group. This is supported by the fact that for the Random group the post-concepts are scored less informal and atypical than their corresponding pre-concepts, which is opposed to what was expected. Comparison of the pre-concepts of the Random group with the post-concepts of the Typological group shows that this effect can not be prescribed to the pre-concepts of the Random group being already so informal and atypical, that it would be hard to produce designs which reflect these features even more. An explanation might be sought in the individual presentation of the precedents, which would make it harder for the subjects in the Random group to put their own work into a larger context, different from their preconceptions. Thus they tend to stick more to their first ideas, resulting in a less flexible design approach.

Finally, by introducing a target group different from the group that was traditionally addressed by the precedent designs, we hoped that the subjects would be forced to reconsider their preconceived ideas regarding the concept "mobile telephone". It was predicted that this would result in post-concepts that were more feminine, asymmetrical and elegant and less formal and typical than the corresponding pre-concepts. This was confirmed for all five product types for the Typological group. The post-concepts of the Random group, however, were assessed as being more formal and typical than their pre-concepts, resulting in final designs which reflect to a lesser extent the requirements set out by the design brief. This last finding again contributes to the positive effects of the product types.

4.7 Discussion

The experiment showed that providing designers with typologically organized design knowledge has a beneficial effect on the results of their design process. Its results are in line with the theoretical framework of chapter 3. Organizing precedents into product types elevates the embodied product-specific design knowledge to a more general, problem-independent level, which can be applied in the generation and development of new design concepts. Moreover, a typological organization helps designers to break away from their preconceived ideas, by making the characteristics of the individual instance secondary to the generic characteristics of the product type. These results have potentially important implications for both design education and the development of design support systems.

First, with regard to the use of examples in design education, they clearly show that examples can be beneficial to designers, if they are organized and presented in a meaningful way. Providing designers with examples organized into product types proved to be such a way. The designers in the experiment which received the typologically organized material, showed a more flexible design approach, sticking less to their pre-conceived ideas than their colleagues, who were provided with the disorganized material. The results of the experiment therefore advocate the use of product types as reference material in design courses and projects.

On the one hand, this could imply confronting students with pre-organized types, such as in the experiment, to train them in perceiving and applying them as pieces of design knowledge in their own design projects. On the other hand, the activity of organizing design precedents into product types by students themselves, can have a strong learning effect as well. Involving searching and discovering order and structure through the assessment of products on different levels of aggregation, such as form, function and meaning, the students would become more aware of the commonalities and differences between products, the fuzzy boundaries between types as well as their mutual relationships. Fundamental here is the notion that the value of these activities is not so much in their physical and tangible output, but much more in the insights the designer acquires while performing them.

Secondly, extending the results to the realm of design support systems almost automatically brings up the concept of a computer database of design precedents, which are organized into product types. Considering the visual character of these types, this can be further specified to a visual database. It would provide the designer with an 'external memory', which can be consulted throughout the form-creation phase. Purcell and Gero (1996) make a couple of statements regarding the structure of such a system. They argue that the examples in the database should range "from the typical to the a-typical within any particular type of artifact". Furthermore, the examples should be connected to each other by means of relevant features, encouraging the exploration by the designer of the possible solution space. Purcell and Gero's experimental results indicate that such a system might have its benefits for the domain of mechanical engineering.

For the discipline of industrial design, however, they express a concern that the development of such a system would be of little point. The knowledge in this domain would not be formalized to the extent that such a database could be successfully structured. And even if this could be accomplished, it would be unlikely that such system would be used by industrial designers, since Purcell and Gero's experiments showed industrial designers to be unaffected by presented examples. All in all, they thus express a rather pessimistic view on the feasibility of such a system for industrial design.

However, the results of the current experiment, combined with the theoretical framework of chapter 3, paint a different picture. First, the experiment clearly indicated that industrial designers are sensitive to examples, provided that these have a relation to the design situation at hand and are organized and presented in a meaningful way. Secondly, the framework only takes salient product features into consideration, which clearly reflect a certain product type. A-typical examples are therefore not part of this specific type, since they would distort its overall expression, but can be typical examples for other types. Since it can not be determined 'a priori' which types are relevant for a certain situation, a broad range of types has to be available for the database to be of general use.

And finally, the theoretical framework of chapter 3 does provide an instrument for the formalization of the design knowledge that is embodied in existing products. By organizing them according to the salient features of their appearances regarding function, form and meaning, each of these products becomes a member of three different typologies. Thus while these typologies make up for the overall structure of the database, the product types provide the connections between the individual products, which in their turn establish connections between the three typologies. Therefore the development of a visual database of design precedents for the domain of industrial design is considered to be a fruitful direction to pursue.

In the next chapter…

the organization of such a database is further developed. By designing an organizing task as a possible procedure to enter precedents into the visual database, a connection between design methodology and interaction design is made. In the task, which involves arranging, grouping and naming products, the organization of design knowledge is thus not pre-determined, but made by designers themselves. Each of the three sub-tasks is discussed in detail, supplemented by the most striking general observations and findings from an experiment in which the task was used. In this experiment two groups of design students performed the task, with one group receiving contextual information in the form of a design brief. The results of the experiment demonstrate the feasibility of a database which may have a starting set of example products, but is essentially built up, organized and extended by a designer himself.