

3 CONCEPT FORMATION IN DESIGN

In the previous chapter the role which existing products play in the generation and development of new form concepts in the form-creation phase of the product design process, was established as the central topic of this thesis. In this chapter this role will be grounded in theory through a review of the literature on the formation of concepts in design. The chapter kicks off in section 3.1 with addressing first the more general issue of the role of 'the old' in creating 'the new'. The theory of 'displacement of concepts' as formulated by Donald Schön, is introduced as a general framework for describing how we can use the old in creating the new. This framework is then further elaborated using the work of George Lakoff in cognitive semantics. Building on the work of Wim Muller in design methodology it is made more specific in section 3.2, by introducing the construct of a product type as a structure for the organization of design knowledge. Grouping together existing products on their typicality regarding function, form and meaning, leads to the formation of three product typologies, which are described in section 3.3, while the nature of product types is discussed in more detail in section 3.4. In section 3.5 a framework is then constructed which establishes the role of existing products in the creation of new product forms. Section 3.6 finalizes the chapter by summarizing its main points.

3.1 The formation of new concepts

Classical theories

In 1963 Donald Schön, a design methodologist, published in a book called "Displacement of concepts", an extensive study on concept formation in general

(Schön, 1963). After reviewing the existing literature on this subject, Schön concluded that the current body of theories on the formation of new concepts in science and technology could be divided into two categories, which both gave insufficient explanations of the phenomenon. As an alternative he proposed a third theory, which he named 'the displacement of concepts'.

The first set of theories identified by Schön regards the formation of concepts as intrinsically unexplainable. New concepts just mysteriously and unconsciously emerge, donated to the world by a divine agency. Because of the inscrutability of this agency, the process of how this donation takes place is also treated as a mystery. New concepts just illuminate from the subconscious, as in the famous account of Kékule, who was presented the image of the benzene ring in a dream, after falling asleep in front of the fire.

At first sight, the second body of theories seems to offer a better starting-point to develop some notions on the relationship between old and new concepts. It states that the process of concept formation needs no explanation at all, simply because all new ideas are merely (re)combinations of old ideas, resulting in new wholes, which are never more than the sum of the old parts. However, if new concepts are build up from parts of old concepts, which in their turn are the result of the (re)combination of parts of even older concepts, which in their turn etc., then how did something get created in the first place? They do see the process having a conscious part, but that only involves the screening of possible combinations rather than the formation of anything new in itself. Again the generation of new concepts is supposed to occur by itself or to be inexplicable.

Both set of theories thus fall short of providing a satisfactory explanation for the formation of new concepts in general, and in design especially. Designers are not visited by divine agents (although some of them are rather pretentious) and all of them will be rightly offended if you state that design is simply about 'putting things together'!

The displacement of concepts

Schön tries to fill the gap by introducing his theory of 'the displacement of concepts'. In this theory, old concepts do not get just literally transferred to new situations, but are to be restructured in response to the characteristics of the new

situation. Thus the familiar becomes a projective model for the unfamiliar, leading to a new way of seeing the unfamiliar as well as the familiar. Schön gives the following example to illustrate his thoughts:

"I know what a drum is. I know about snare, bongo, bass, and oil drums. But when I found myself in a metal room with a thin metal wall that reverberated whenever it was jarred, it was a new thought for me that the room was a kind of drum"

Here the old concept of 'drum' is 'displaced' to fit a situation outside its ordinary pattern of use, in this case a room, which peculiar characteristics intimate to the perceiver the concept of 'drum'. By taking this concept as a projective model for the metal room, drum-like characteristics can be attributed to it. This in turn then allows expectations from the 'drum' concept to get carried over to the particular instance of the metal room. Thus, for example, one can predict that increasing the volume of the room will result in a deeper sound when the wall is reverberated. As a result of this process, the old concept of 'drum' has been extended to include the previously unfamiliar instance of the metal room, while at the same time the metal room becomes 'a kind of drum'. This in contrast to the application of a concept to a familiar instance, in which the instance is merely found in the concept, without any change in the way in which the concept is perceived. In this case this would apply, for example, to the inclusion of a timpani in the concept 'drum'.

The process of displacement

Schön distinguishes four phases in the displacement of concepts: 1. transposition, 2. interpretation, 3. correction and 4. spelling out (pp.53). These phases are heavily interrelated and often do not follow each other in this fixed order. Transposition involves the first establishment of the symbolic relation between the old and the new. In the example of the metal room the thought that "the room was a kind of drum" connects the concept of drum to the situation of the room. Interpretation then assigns the old concept to a specific aspect of the new situation, in case of the room to the reverberation of its thin metal walls. Interpretation is necessary, because not all aspects of the new situation might

lend themselves to being viewed in terms of the concept. Although the metal room might have drum-like qualities, it does not immediately imply that it would lend itself to be used as an instrument in a rock band ³.

Before displacement the new situation itself possesses an existing structure, which might interfere with the structure of the old concept that is being projected upon it. Correction thus involves the adjustment of both the old concept as the new situation in order for them to 'fit'. This mutual adaptation might involve the rejection of certain aspects of the old concept, as being inapplicable to the new situation. For example, the image that a drum is portable, so that it can be used in a drum band, can not be carried over to the situation of the metal room. Those aspect of the old concept that are suitable for interpretation, may also change. Through the reverberating walls of the metal room we may come to treat the skin of the drum as it's walls. In this way the metaphor of 'drum' is being stretched to include the notion of a drum as an 'space, enclosed by walls'. The final phase in the displacement of concepts involves the spelling out of the metaphor, which is about establishing the areas of community and difference between the old and the new concept.

Selection of concepts for displacements

Thus the main distinction between the displacement of concepts and the literal application of concepts to instances is in the fact that in the first the relation between the old concept or theory and the new situation is a symbolic one. The old concept is taken as a 'program' for the exploration of the new. Through this program expectations of the new concepts can be formed, relationships between aspects of the new concept can be envisioned and qualities of the new concept can be predicted. However, although this theory provides an explanation for the part the old plays in creating the new, it merely shifts the focus of attention to a

³ It might, though! The German avant-garde band Einstürzende Neubauten was famous for their use of walls, pipes and ventilating-shafts as instruments in their music. Other instruments included metal bars, cellular phones, vases and brushes, car tires, free falling objects etc. – not to mention the more conventional pneumatic pistons and drills.

new problem: how do those concepts affording displacement, force themselves upon the perceiver of the new situation?

Schön lists three factors which would influence the selection of concepts for displacement (pp. 72):

- The theory-resources of the various cultures to which we belong, with all their overlapping priorities, given and sometimes imposed by our language, including,
- The metaphors already underlying our theories of the new situation, and
- The demands of the situation itself 'asking' to be straightened out in certain ways.

The many cultures we are part of provide us with a rich repertoire of theories, notions, ideas, memories, phrases etc., from which metaphors can be derived for displacement. Reflected in our language, it is our vocabulary through which we understand and reason about the world. In time, several metaphors from one part of our culture have been transposed and elaborated to different parts of society. For example, projecting the view of a stepladder to our social system has led to phrases as 'a social climber', or 'moving up in the world'. As was stated before, the new situation also possesses a pre-structure, which is reflected in the language we use to describe it. This particular set of language also induces a particular set of metaphors for displacement. The interaction between this body of culturally-induced metaphors and the demands of the new situation then becomes the filter for the selection of the appropriate metaphors. They become chosen on their ability to meet the demands of the new situation.

However, in the displacement of concepts, this ability only manifests itself when the metaphor is being elaborated, making the determination of its appropriateness to the current task an after-the-fact process. To find a solution to this problem Schön eventually falls back to the notion of intuition, in which the selected metaphor has some kind of 'pull' about it which makes it more suitable, intriguing, applicable or fitting for the job than others. How this 'pull' manifests itself to the perceiver, however, is left undealt by Schön.

Classification

A possible explanation might be found in the work of George Lakoff (1987) in cognitive semantics. It states that the formation of new concepts is rooted in our

capabilities to organize our world by means of classification. Classification is a fundamental and purposeful human activity. We make sense of our world by putting objects, situations, people etc. based on some shared characteristics into conceptual categories. These are then each labeled with a name, which is then used as a reference for all the elements in a category. Through classification cognitive structures are being formed, which contain the set of beliefs and expectations for the items in a certain category. These structures have been termed as schemas, concepts, frames etc. (Cohen, 1982). They provide an organizational structure for interpreting new information about instances of a category as well as for predicting their characteristics. Thus schemas enable us to reason about the world through inference. Classification makes it possible to share thoughts, notions and ideas about a specific element in a category or the category itself without having to list all characteristics.

Levels of classification

Remember the third task described in the beginning of this thesis, in which you were asked to imagine "kitchen chairs, which fit into a modern, Italian-like kitchen, look elegant and stylish but not fragile, are marketed at young professionals, age 25-40, and cost less than \$300"? Unless you are an expert on this particular area, you almost certainly could not easily come up with a large range of examples. This in contrast to the first task, where you had to visualize examples of the much general group of just 'chairs'. This indicates that there are certain categories which can be more easily retrieved from memory than others. These categories have been defined as 'basic-level' categories, being at the level of knowledge organization on which (Muller, 2001):

- the members of the category have similarly perceived overall shapes ('Gestalts');
- we have one exclusive mental picture of the entire category;
- we are quickest at identifying an object, thing or event;
- we have the shortest, most commonly used, neutral words available for labeling category members;
- the most culturally-determined functions of objects are defined;
- we use similar motor programs for interaction with the members of a category.

Thus in basic-level categories our knowledge is stored in the most economical way, enabling us to interact with our environment in the most effective way. The concept of 'drum', as referred to in the discussion of Schön's work, as well as 'chair' are examples of basic-level categories. You were able to perform the first task in the introduction of Chapter 1 without much trouble, because in time you have created a 'mental box', labeled "chairs", containing a large number of instances of all kinds of chairs. Besides the basic level, two more levels of organization can be distinguished: the more general, super-ordinate level and the more specific, sub-ordinate level.

On the super-ordinate level, basic-level categories are grouped on a higher-order in order to establish a broader context. Thus instances from the basic-level category 'chair' can be grouped with, among others, instances of the basic-level category 'table' in the super-ordinate category 'furniture'. Organization on the sub-ordinate level involves further specification of basic-level categories. By assigning an object to a category on a sub-ordinate level on the basis of some distinct properties, other properties can be predicted, which were not explicitly observed. For example, the category "kitchen-chairs" is a subcategory of "chairs". So, besides those properties which are specific for a kitchen-chair, like the angle between the back and the seat of the chair which affords an upright sitting position, all properties of the category "chairs" are also present in the elements of the category "kitchen-chairs". Seeing a specific kitchen-chair thus makes it possible to derive that it is a piece of furniture, which can be made of different materials like wood, steel or rattan and can be combined with a matching table.

Concept formation through projection

Lakoff argues that our classification capabilities, which get established through our perceptual and senso-motorical experiences of the world, provide us with the necessary means for the formation of new concepts. Concept formation can now arise through:

- projection from basic-level categories to super-ordinate level categories;
- projection from basic-level categories to sub-ordinate level categories.

Returning now to the issue of the selection of concepts appropriate for displacement to a certain new situation, we can be a little more specific. Each new situation possesses a structure prior to the process of displacement. This pre-structure might induce many different basic-level concepts, affording projection to both super-ordinate and sub-ordinate level categories.

The first kind of projection involves organizing knowledge on a higher level of abstraction, by putting together objects in a broader functional context. Grouping instances from the basic level 'chair' together with other instances on the super-ordinate level 'furniture' enables the transfer of knowledge from the concept 'chair' as input for the creation of a new furniture concept. The second kind of projection brings together knowledge on a more specific level. By grouping together instances of the subcategory 'kitchen chair', social and cultural knowledge concerning people's cooking habits, dining environments, eating rituals etc. is being 'unlocked', which might feed the generation of a new dining concept.

3.2 The nature of the form-creation phase

So far the theory of the displacement of concepts has been identified as a possible instrument for describing the role of the old in creating the new. It defines old concepts as programs for the exploration of the new, thus enabling the formation of expectations and qualities of a possible new concept. Possible candidates for displacement would present themselves as basic-level concepts that can be distinguished in the existing structure of the problem situation at hand. Projection of these basic-level concepts on either a more general or more specific level would enable new organizations of knowledge, resulting in possible novel solutions. This general framework of concept formation will now be made specific for the form-creation phase of the product design process.

From function to form

Starting from a given solution principle, the form-creation phase marks the essential translation of function to form. Designing is concentrated on the development of the visuo-spatial and material qualities of a product, both in

relationship to its form and as a means to establish the desired semantic qualities in relationship to its use. To become accepted by society, a new product will have to reflect certain elements of convention, which have developed through time in the relation between the form, the function and the meaning of a product. A kitchen chair will have to express its function through its form, so that users can perceive its intended ability (to sit) without having to consult the designer. However, the spatial and material properties of the chair not only have to denote this primary function, but also connote secondary functions like the way of sitting (straight up, so the food can be better digested), the socio-cultural environment in which the chair is supposed to be used (modern, Italian-like kitchen) as well as stylistic expressions, such as "elegant, "stylish" and "fragile". Possible solutions will also have to fit within the context set by other external conditions like price (\$300) or marketing issues (young professionals, age 25-40). This process is gets even more complicated by the fact that these fore mentioned elements of convention are not constant in time. What is 'in' this year, might be 'out' next year. Products made from translucent plastics in iMac™ colors might be a huge hit today, they could be totally outdated in six months.

In his book "Order and Meaning in Design" (Muller, 2001) Wim Muller presents a scientific approach to the form-creation phase. He argues that the focus of attention in this particular stage in the design process on a product's overall appearance as a 'Gestalt', calls for a specific form of classification, called a typology. Three product typologies can be formed, each organizing design knowledge on a different organization level. Together they put up a multi-layered structure, which affords the displacement of concepts through projection to different levels of knowledge.

Ill-structured design problems

The multi-faceted and intertwined structure of design problems have let design methodologists to label them as 'ill-structured' or 'wicked' problems (Rittel and Weber, 1984). Ill-structured implies that these problems are essentially unique, meaning that no classes of problems exist in the sense that solution templates can be developed to fit all members of a class. Thus no homogeneous sets of

knowledge can be generally applied, leaving the designers only with 'rules of thumb' which still need interpretation to fit the task at hand.

Spiro et al. (1987) argue that the transfer of knowledge in complex content domains such as design, should be based on case-based presentations. These should be explored by re-examining each case in the various contexts of different neighboring cases, using a variety of dimensions for comparing cases. To acquire such flexibility, each complex case needs to be decomposed and represented along many partially overlapping dimensions (i.e. the same information must be represented in different ways). Instead of the retrieval of a precompiled schema, situation-specific schema's will have to be assembled from the knowledge fragments, that resulted from decomposition. Many connections must be drawn between those knowledge fragments, so that many possible routes for future assembly can be established and many potential analogies for understanding new cases can be created.

The process of classification will now be introduced as a possible instrument to decompose the design knowledge that is embodied in existing products into smaller knowledge fragments. It will be argued that a special kind of classification, called typification, is necessary to accommodate the specific needs of the product design process.

An argument for typology

The classical view on classification does not allow for an instance to be 'more' or 'less' a member of a class; it either falls within or outside the class. Thus drawing the boundaries between classes becomes the key factor in the formation of a classification. Once the borders have been set, assigning an instance to a class merely becomes a matter of 'getting it to fit'. A typology is, as is a classification, the result of arranging a collection of objects into a series of groups. In contrast to the classical view, however, the objects are not to be mutually compared on their discrete features, but on so-called 'Gestalt' features, which determine the objects' appearances as 'wholes'. Grouping objects through visual abstraction (looking at them 'through the eyelashes' is an appropriate technique for this) thus results in a graded structure with fuzzy boundaries between the groups. To distinct this process from the conventional classification, it will be referred to it as

typification and its result as a typology, consisting of an overview of types. Finally, typicality is defined as the extent to which an instance is part of a certain type.

3.3 Three product typologies

Previously it was stated that the development of a product's visuo-spatial and material appearance is controlled by the understanding that, in the relation between (a) the function of a product, (b) the form of a product and (c) the meaning of the product, elements of convention must be present in order to advance new products to become 'shared' properties in society. This notion will now be extended by stating that these elements of convention are reflected in salient 'Gestalt' determining features of the product's appearance, defining the product's typicality regarding function, form and use. Three different product typologies can now be formed through the typification of a collection of product instances: 1. a *typology of function*, 2. a *typology of form* and, 3. a *typology of meaning*. In this view a distinction is made respectively in a typology concerned with 'forms' of conditioned behavior, in a typology that deals with the physical forms of designed artifacts, and in a typology dealing with 'forms' of conventional behavior and meaning.

A typology of function

The formation of a typology of function proceeds through grouping product instances sharing a primary function or intended ability to use. Strictly theoretically speaking, a product is *assigned* a primary function if a user associates the properties of a product, which are derived from its appearance, with a goal that has to be achieved. However, if there would be no conventions between form and function this would imply that a user, in order to establish the connection between a desired goal and the available properties, would have to consult the designer about the intended ability of the product's use. Thus, if someone is confronted with a product he is not familiar with and its use is unknown in the community he is part of, in which case no 'conventions' between the product's form and function are at his disposal, he would have to guess about the intended use. Fortunately, however, once a product is in use, its appearance

becomes an indication of its possible use. Thus, through time, for each primary function a common representation in the form of a spatial schema has been established, that is used to determine the function of the product from its appearance. Those 'Gestalt' determining features of the product's appearance that make up this common representation, reflect the elements of convention that have been established in the relation form-function and as such form the functional framework on which variations in form and meaning are based.

For typification purposes, each product instance can now be regarded as a member of a product type on the basic-level', e.g. the product types 'chairs' or 'tables'. On a sub-ordinate level a differentiation can be made into product types, indicating a specific application, utilization or user environment. From the basic-level 'chairs' this create product types like 'kitchen chairs', 'office chairs' or 'rocking chairs'. Product types can also be grouped on a super-ordinate level, creating in this way a hierarchy of product types. 'Chairs' and 'tables', for example, thus become assimilated into the product type 'furniture'.

A typology of form

Grouping together product instances with respect to the visuo-spatial organization of their appearance, material construction and manufacture, leads to the formation of a typology of form. Those 'Gestalt' determining features which make up for the product's visuo-spatial and material qualities, can thus be identified as the elements of convention, that have developed in the relation form-meaning. Muller distinguishes three different levels of ordering principles underlying possible organizations in phenomenal space, each with their specific ordering dimensions:

1 a space-topological ordering level,

dealing with the orientation and arrangement of the elements that make up the spatial structure of the product form;

On this level product types can be distinguished that typify the way in which a product form relates to the phenomenal space, i.e. the space as is experienced by human beings. It is experienced as asymmetrical because of the anisotropy of different space-orientations. The orientation of the elements of a product form in

the phenomenal space as well as the disposition of these elements in that space, will give rise to typological differences like: 'horizontal or vertical directed', 'disposed side by side', 'backwards' or 'upwards', 'symmetrical' along a 'vertical or horizontal axis'.

2 a form-typological ordering level,

dealing with the basic shapes of the elements of the product and their composition;

Typification on this level can be achieved by reducing the geometrical forms of products into a limited number of primitive shapes in two- and three-dimensional space. These are respectively, square, triangle, circle and cube, cylinder, sphere, cone and torus, plus all shapes that can be obtained by a dimensional transformation of these primitives. In this way a rectangle is considered as the product of a dimensional transformation of a square in 2-D space, the ellipsoid as the product of a similar operation of a sphere in 3-D space. Since all primitive shapes have a 'geometrical' and a 'closed' character, complementary features as 'organic' and 'open' can be assigned to a product form on this level as well. Thus product types labeled '2-D rectangular', '3-D cylindrical, or 'Organic' can be formed on this level.

3 a material-morphological ordering level,

dealing with the quality of the materialized form, its kind of construction and its material composition.

On this level all product forms are typified according to the way(s) in which their material qualities constitute two- or three-dimensional space: Linear, Flat or Solid. Further types can be distinguished which represent a more specific characterization of the formed material; linear formed material can be straight, or curved, flat formed material can have no bending, be single- or double-bent. Finally, in constituting space a product form can be singular or composed, structured or not.

A typology of form, resulting from a typification of product instances on these three levels of ordering, will also denote specific visuo-spatial and material qualities of the product form that articulate how the ordering is perceived. Thus the dimensions orientation and disposition will give rise to typifications like

'neutral', 'balanced' or 'dynamic' on a space-topological level. On a form-topological level, the perception of the plasticity of the product form will induce typifications like 'fragile', 'elegant', 'robust'. Finally, on a material-morphological level, perceptions of the construction and materiality of the product form will lead to typifications like 'transparent', 'sustainable', 'soft' etc

A typology of meaning

The formation of a typology of meaning proceeds through grouping product instances sharing a way (or ways) of use and all the connotations involved. The identification of those 'Gestalt' determining features of the product's appearance, that connote its character, style and sphere of use, and its meaning and value in relation to the socio-cultural behavior of its users, establishes a organization of design knowledge of culturally defined behavior and interactions in the usage of products. Here, also, conventions have been established: Within a collection of products that share a primary function, for example 'to sit', different types can be distinguished according to the way the product is being used: ways to sit, expectations of the act of sitting and intentions concerned with it. Attention to the socio-cultural environment of use will result in the identification of types like 'domestic', 'professional' or 'recreational'. Differences in the historical environment of use will result in product types as 'Classicist', 'Functionalist' or 'Pop & Pomo', with additional typifications like 'Baroque', 'Rococo' of the first, 'Arts & Crafts', 'Jugendstil' for the second and 'Populux', 'Pop-art' in the third case. Since style is not restricted to products with a similar primary function, the 'Baroque-style' of a specific chair will extend to other 'furniture' as well. Finally, the kind of behavior associated with the product's use, will induce the formation of product types like 'impulsive', 'childish' or 'macho'.

A hierarchy of typologies

Through the typification of its appearance with respect to function, form and meaning, a product instance becomes a member of each typology, linking them together in a hierarchical way. A typology of function provides the basic-level from which connections can be made to a super-ordinate level by means of the typology of form, and to a sub-ordinate level by means of a typology of meaning.

Thus the three kinds of product typologies together put up a hierarchy of design knowledge, which enables the generation of new concepts through projection in the two previously identified directions. For a detailed specification of each typology the interested reader is referred to Muller, 2001.

3.4 The nature of product types

The previous sections have established the product type as an important knowledge structure in design. By organizing design precedents into groups based on shared 'Gestalt' determining features of their appearances, the design knowledge that is embodied in these precedents becomes available on a problem-independent level, affording application in new design situations. Concept formation in design has thus been defined as a process which comes about through the operationalization of a collection of product types. Three different typologies, resulting from classifying design precedents based on shared properties regarding function, form and meaning, have been defined, together constructing a framework of design knowledge which can support designers in the form-creation phase. The concept of the product type as a design knowledge structure will now be further detailed by drawing further reference to research on classification and concepts.

The features of product types

In its most basic form, classification can be defined as the process of arranging items into classes. It involves the progressive reduction of variable inputs to a smaller number of equivalence classes, whose memory representations, called concepts, mediate thinking and adaptive action (Schyns, 1997). Up until this moment the properties of a product that determine its classification in the three typologies, have been simply indicated as the 'Gestalt' determining features of its appearance, i.e. those features that define the product's whole, overall shape. These features will now be further described using a division made by Smith and Medin (1981) of the kinds of properties that direct an object's classification.

First of all, a distinction is made between *component* and *holistic* properties. A component property is defined as a property that helps to describe

an object, but does not constitute a complete description of the object. Thus for a chair, component properties might include: having a set of four legs, have the average shape of a chair, and the fact that it is meant for sitting. So components might refer to parts of the object (legs), global aspects of the object (shape) or the function of the object (sitting). A holistic property, in turn, offers a complete description of an object, represented by some sort of 'ideal' template, which is sufficient to represent the complete object class. The distinction between depicting an object's overall shape by means of a component property or a holistic property might seem minimal at first sight. However, two factors make up for their difference. First, since components properties offer an incomplete description of an object, there is usually more than one component necessary to fully determinate an object's class. This in contract to an holistic property, which on its one provides a sufficient description. Secondly, a component property offers an abstraction from the object, while a holistic property is more intended as a point-for-point isomorphism.

Components can be further broken down into *dimensions*, which are quantitative and *features*, which are qualitative. For example, chairs could be represented in terms of dimensions by the height of their seating and by the angel between seat and back. A representation in features might include: having arms, made of wood, foldable. So while a dimension determines differences between two objects in terms of their value on this dimension, a feature indicates a difference between two objects merely by its existence or not. A further difference between dimensions and features can be found in the way they describe a class of objects. A description in dimensions usually involves a small number of dimensions, on which each object has some value on. Feature descriptions are likely to use many features, which can include some which are not applicable to all the objects in a class.

Finally, three different kind of features can be discriminated: *perceptual*, *abstract*, and *functional* features. Perceptual features are those corresponding directly to outputs of the perceptual system. For example, the presence of a curved line or a horizontal surface. Abstract features are on the other side of the scale. They only have minimal connections to perceptual experience, and thus cannot be directly read off on object's appearance but have to be derived from it.

To quote Smith and Medin (1981, p.19): "The only solution is that one must have some knowledge that is capable of mediating between the features at the two level; that is, to determine whether an abstract feature is perceptually *instantiated* in an object, one must have recourse to ancillary knowledge about the relation between abstract and perceptual features".

Functional features are somewhat in-between. As stated earlier, strictly theoretically speaking an object is only assigned a function once a user associates the properties of the object, which are derived from its form, with a goal that has to be achieved. Once an object is in use, its appearance thus becomes an indication of its possible use. Thus, through time, for each function a collection of objects has been developed, from which a common representation can be derived that is used to determine the function of the object from its form. For example, typifying an object as a 'chair' puts it amongst other objects, which all afford the conditioned behavior we have called 'sitting'. So, although the reason actually is lying *outside* the object itself, classification does take place based on perceptual features which refer to the object's function.

Applying this division to the three product typologies results in the following insights. First, although it has been stated that it is the product's overall shape that has to be considered for classification, this does not imply that one, holistic property is sufficient to fully describe the product. The decomposition into types representing function, form and meaning implies a description based on components. However, the notion of the pre-concept, which has been defined as organizing a designer's existing, pre-situational design knowledge regarding a products' function, form and meaning into a pre-conceptual image, does fit the description of a holistic property.

Second is the choice between features and dimensions. Describing products in terms of dimensions would imply that dimensions have to be found which can be applied to all products. Although a number of these might be defined, such as volume, weight, etc., these dimensions are irrelevant when it comes to designing new product forms. To be useful such dimensions would have to be decomposed in features such as open, fragile etc. Furthermore it has been argued that in a typology it is the central tendency, which is manifested in the most typical instances in a class, that is of the most interest. A feature will then

be only attributed to a product when its salient properties are to such an extent typical that the class' central tendency is represented. Thus a description in features does match the characteristics of a typology better than a description in dimensions.

The breakdown into functional, perceptual and abstract features elegantly parallels the distinction in a typology of function, a typology of form and a typology of meaning⁴. The typology of function is based on a product's functional features, which indicate its ability for use. A typology of form is clearly realized through a typification based on perceptual features, which constitute the product's external shape. Finally, a typology of meaning is based on abstract features, which have to be deduced from the product's external shape.

The formation of product types

Product types are thus formed by classifying products into classes based on functional, perceptual, and abstract features. But how does this process come about? Do products end up in the same class because they look alike or do they merely look alike because they are in the same class and is the actual reason for grouping them together not directly related to their appearances? Through research into classification strategies and procedures, two dominant views have been developed in time, which describe the process of classification: 1. *similarity-based* classification and 2. *theory-based* classification.

Similarity-based classification has as its most basic premise that objects are put together because they *look* similar. The resulting concept is equivalent to a list of features and thus class membership judgment becomes a function of determining the similarity between the features of an instance and the features of a concept. Representatives of the similarity-based view of classification are the *classical model*, in which a concept is defined by a set of critical features; the *prototype model*, in which class membership would be decided on the basis of an item's similarity to an abstract mental representation of the class, which does not

⁴ Muller (2001) calls these prototypical features, solution-typical features and behavioural-typical features. To avoid confusion with the prototype model of classification, this terminology will not be used here.

have to exist in real-life and is called a prototype (Rosch, 1975); and the *exemplar model*, in which an instance is matched to a set of earlier encountered real-life examples.

Although the classical view provides for a well-defined classification procedure, its use is limited to classes which can be specified by a set of defining features. These may be found in such a strict domain as mathematics, in real-life, however, their presence is extremely rare. Just think of a simple concept as "table" and try to come up with a core set of features that all tables and only tables must and do share. A further problem is that research has shown classes to have graded structures, implying that certain class members are better examples of the class than others (Mervis and Rosch, 1981). These 'typical' or 'good' examples tend to be named first in free recall of class members and are classified faster and learned more rapidly than less typical instances. For example, a sparrow is judged to be a better, more typical bird than an ostrich. While both the prototype model and the exemplar model by means of their formulation allow for natural categories with fuzzy boundaries and graded structures, they also bring up a number of other problems. First, how is determined what a characteristic attribute is and what not? Secondly, reducing classification to the process of making lists of features provides an over-simplified and perception-biased view of people's conceptual knowledge, discarding any non-perceptual information.

Theory-based models of classification propose that conceptual categories are formed based on a more-rule like or theory-like semantic representation (Murphy and Medin, 1985; Rips, 1989). Objects, people or events end up together in a class because their grouping is best *explained* by a certain theory, intention or history. Features are not seen as independent, but as related elements in networks of information, in which concepts are considered to be more than just the sum of their parts. A further important difference is that theory-based models also incorporate non-perceptual information into their concept formation. Thus classification would not solely based on an item's visually perceptible, surface properties, but also on information regarding the context in which the item exists. Although in most cases it is highly likely that the items in a class may turn out to look very similar, it is not the main reason for their grouping together. One could even say that we see things as being similar because of their

class membership, rather than classifying them because of their similarity (Hampton, 1998). Representatives of the theory-based view of classification are the *psychological essentialism* model, in which objects are grouped together because people believe them to share essences or underlying natures, i.e. properties which make the object what it is, and without which it would be not that kind of object; and the *intentional-historical* model, in which an object is assigned to a certain class, if its current appearance and potential use are best explained as resulting from the intention to create a member of that specific class (Bloom, 1996).

The theory-based view thus considers concepts to be represented by more than a list of features. Due to its abstractness, however, it falls short in providing a clear classification procedure. To predict whether an object is a member of a certain category, it is insufficient to just know that contextual information and background knowledge has to be taken into consideration. Given the problems both views have of explaining all acts of categorization, some researchers have argued that people can apply multiple procedures of categorization to the same items, perhaps even simultaneously (Smith, E. et al., 1998).

Projecting both views of classification to the formation of the three product typologies leads to a number of insights. Grouping products into product types which deal with their actual physical forms, as in a typology of form, brings out technological knowledge about the spatial and material ordering of products. The basis for this typology is thus found *inside* the product itself. For example, typifying a product as 'organic and open' places it within a collection of other products, which *internal structure* holds the same features. Clearly this kind of typification is based on the product's visual, perceptual properties, corresponding to the similarity-based view of classification. Products end up in the same product type because they *look* similar, even though they might fulfill different functions. This is in contrast with the other two typologies, which both deal with kinds of external behavior associated with products: a typology of function concerning 'forms' of conditioned behavior, a typology of meaning concerning 'forms' of culturally defined behavior. As a consequence the basis for these typologies is found *outside* the product itself.

For a typology of function, however, which organizes products sharing a solution principle, a discrepancy between theory and practice has already been indicated. Because in theory a product does not have a function, a user will have to derive it from the product's particular spatial form. To do so, knowledge from previous experiences with objects having the same form will have to be operationalized. The theory-based, intentional-historical model seems very appropriate to describe this process. To assess if an is to be classified as a chair, one has to determine how likely it is that it was successfully constructed with the intention to be a member of the class of chairs.

Finally, the basis for organizing products into a typology of meaning is found in domain-specific knowledge, that has been acquired through interactions with products that offer similar kinds of experiences. Such interactions and experiences, however, can not be directly read off a product's appearance, but have to be derived from it. Thus similarity of use and behavior instead of similarity of form dictates the formation process of these kind of types, indicating a theory-based classification. For example, typifying a pair of shoes as 'sporty' places it amidst clothing, watches, glasses, cars etc., which refer to a culturally defined behavior that is called 'sporty'. In fact, the real 'objects' to be grouped together here should be the products' users, which reflect this kind of behavior, while the products are merely affording it.

The structure of product types

Besides the differences in strategies people use while classifying, a further relevant distinction can be found in the structure of the categories people create. Barsalou (1983) identified two important kinds, which he indicated as *taxonomic* categories and *goal-derived* categories.

Taxonomic categories are related to one another by means of class inclusion. A well-known taxonomy is the biological one, in which the category "mammals" includes the category "dogs", which in turn includes the category foxhounds. A specific dog can thus be classified as a foxhound, as a dog or as a mammal. These three levels of inclusiveness correspond to the previously distinguished super-ordinate, basic and sub-ordinate level, with the basic level as the most preferred level.

Goal-derived categories, however, are created ad-hoc of items that relate to a certain goal achievement. Although these items may be physically dissimilar and initially not associated with each other in memory, together they are good examples of things that serve the goal of the category. Barsalou gives as an example 'things to take on a picnic in the mountains'. The goal of 'having an enjoyable dinner out in the open on a high altitude' could lead to the grouping of previously unassociated items as a barbecue, a raincoat, a box of matches, and a large piece of wood for holding off any hungry bears.

Applying this distinction to the three product typologies reveals some more about their structures. The typology of function clearly is a taxonomic category, in which the products are organized on the familiar levels, which most people use for communication. The basic level "chair" has the category "furniture" as its super-ordinate level, and categories like "dining chairs" and "office chairs" as possible sub-ordinate levels. The typology of form shows a similar structure. By typifying a product on a space-topological ordering level, dealing with the orientation and arrangement of the elements that make up the spatial structure of the product form; a form-typological ordering level, dealing with the basic shapes of the elements of the product and their composition; and a material-morphological ordering level, dealing with the quality of the materialized form, its kind of construction and its material composition, a hierarchy of design knowledge regarding products' spatial and material qualities

Finally, design is by nature a goal-directed activity. The goals which are stated in the design brief will have to be expressed by the designed solution. Organizing product based on their abstract features as in a typology of meaning provides a designer with a means to establish relationships between goals, coming from the products' external environments, and solutions, as constituted by products' internal structures. For example, the product type 'sporty' may be derived from the goal of 'reflecting a sporty lifestyle', which could include such objects as a pair of basketball shoes which is also worn by Michael Jordan, a pair of glasses made from the same materials as mountaineering equipment or a red Ferrari, worth \$150.000. Analyzing these products on their spatial and material qualities provides the designer with knowledge regarding the design of sporty products.

3.5 Concept formation in the form-creation phase

A framework can now be constructed for describing the role of existing product instances in the creation of new product forms. First, the design knowledge which is embodied in a product's visuo-spatial and material appearance, is decomposed into smaller fragments through of the creation of product types. These product types are, in their turn, part of one of three product typologies: a typology of function, a typology of form and a typology of meaning. Finally, since each of these three typologies represents a body of design knowledge on a different level of organization, respectively a basic-level, a super-ordinate level and a sub-ordinate level, a multi-layered structure is established, which affords the displacement of concepts through projection from the basic-level to both of the other levels. Throughout the form-creation phase the designer alternates between these three different levels, constantly generating and developing new and meaningful organizations of design knowledge in a visual form.

Product types as carriers of problem-independent design knowledge

By grouping product instances into a product type, the characteristics of each instance become secondary to the characteristics of the type. In this way the product-specific knowledge, that is embodied in the instance is taken to the more generic and problem-independent level of the type. Suppose you could take snapshots of all the mental images of chairs you could think of in the first ask of Chapter 1 and put them on display on a large wall. You would then easily notice that, although probably vary diverse in form, material and color, all these chairs have certain characteristics in common which enable a user to perceive their intended ability: to sit. However, besides these commonalities, each chair also possesses many unique characteristics, which show the dimensions of the solution space of the concept "chair". These unique characteristics can also become commonalities, if some of these chairs are being grouped with other products to form, for example, the type "elegant". In this way connections between product types get established, leading to a integrated network of design knowledge.

Product typification as a design technique

The act of product typification, in which existing product instances are grouped into product types, thus is considered to be a powerful design technique. Design learning and experience is considered to be characterized by the ability of the designer to generalize a unique design situation through typification of knowledge, that has been acquired in experience with existing designs and previous design situations. Typification is a form of generalization, in which the abstraction and classification of salient features of precedent designs plays a key role in both organizing and applying design knowledge.

Organizing existing product instances into product types through typification involves searching and discovering order and structure through the assessment of products on different levels of aggregation of form, function or meaning. In this process the designer becomes more aware of the commonalities and differences between products, the fuzzy boundaries between types as well as their mutual relationships. It also enhance the designers' sensitivity for design details and nuances, since it forces him to attentively observe and compare products on different levels of abstraction

The designer as an organizer of design knowledge

Throughout the form-creation phase, the thinking and acting of the designer is directed towards the creation of new and meaningful organizations of design knowledge. New, in the sense that they reflect certain original characteristics, that distinguish them from previous organizations. Meaningful, in the sense that they afford experiencing the design situation in a significant perspective. Visual representations, such as sketches, mood boards or collages, provide the designer with powerful means to externalize these organizations into concrete form concepts. By means of transformations of these visual representations, both internal and external, designers move through the form creation process from problem to solution.

The formation of new concepts now comes about through the operationalization of a collection of product types, that has been build up in time, by the designer through the typification of existing product instances. Because of their problem-independent character, product types, in contrast to product

instances, can serve as projective models for the displacement of concepts to new situations. They are holding environments for design knowledge that can be 'read off them', allowing the designer to 'see' possible implications of an intended move in the design process. Bringing a new concept through the identification of its salient features within the context of a specific product type, enables the designer to make 'educated guesses' about the implications of certain design decisions.

For example, let's consider the design problem of the third task of the introduction of Chapter 1, demanding the design of a "kitchen chair, which will fit into a modern, Italian-like kitchen, looks elegant and stylish but not fragile, is marketed at young professionals, age 25-40, and will cost less than \$300". This particular design situation might induce such basic-level concepts as 'chairs', 'kitchen environments', 'Italian', 'professional' or 'elegance'. Notice that the description of the situation in linguistic terms forms an important step in the identification of the basic-level concepts that are in play. These basic-level concepts now present themselves as starting points for the two kinds of projection that have been previously described

Projecting the product to be designed within the context of existing product instances, that have been grouped together on their similarity regarding their semantic qualities, brings about the identification of those 'Gestalt' features of the new product's appearance that could express these qualities. In this way information can be built up before the actual creation of a product form starts, in order to identify the semantic solution-space of the product to be designed. Korobkin (1976) has labeled this kind of information as 'image-information' as distinguished from 'test-information' which is put down into a list of requirements. While the first deals with visual material as a product of synthesis, the latter is a product of analysis, usually in the form of textual statements. This image-information provides the designer with an image of the product's external responsiveness, regarding those features which will fulfill external conditions coming from the product's environment.

In a generative sense, a new product's function provides a starting point on a basic-level, from which projections can be made to the super-ordinate level to product types, which have been formed on their similarities with respect visuo-

spatial appearance, material construction and manufacture. These types can then be evaluated in view of their behavioral consequences in which the image of the product's external responsiveness that has been built before, serves as a frame of reference. In this way, throughout the form-creation process, formal qualities can be matched with semantic qualities. This will provide the designer with knowledge regarding those features that are concerned with the internal coherence of the product form.

Thus, throughout the form-creation phase, the designer is constantly involved in creating and reviewing a product's perceptual features in a) in light of the required functional features, which make up for its intended primary function and b) in the light of the desired abstract features, which make up for its intended secondary function(s). It is precisely this kind of design knowledge that is essential in the design of new product forms, since it bridges the gap between problems and solutions.

3.6 Summary

The main points of this chapter can thus be briefly summarized:

- An existing product embodies, in its visuo-spatial and material appearance, design knowledge regarding its function, form and meaning;
- This design knowledge is reflected in salient 'Gestalt' determining features of the products' appearance;
- These features can be distinguished into 1. functional features, which refer to a product's function, 2. perceptual features, which refer to a product's form, and 3. abstract features, which refer to a product's meaning.
- Three different product typologies can be formed by classifying a collection of product instances on their typicality with respect to these features: 1. a typology of function, 2. a typology of form, and 3. a typology of meaning.
- Each typology is made up of a number of product types, consisting of product that shared certain features.
- In a product type the product-specific knowledge of its members becomes organized on a problem-independent level, affording transfer to new design situations;

- The formation of new form concepts develops through the displacement of relevant product types to the new design situation;
- The selection of product types, appropriate for displacement, results from the demands of the new design situation, which present themselves to the designer as relevant basic-level concepts.
- From these basic-level concepts projection can take place to the super-ordinate level, to identify relations between forms, materials and certain kind of functions of products, and to the sub-ordinate level, to identify relations between forms, materials and socially and culturally determined uses of products.
- The designer is regarded as an active organizer of design knowledge, who alternates between different levels of organization in order to bring problem-independent design knowledge into the process of generating and developing new product forms.

In the next chapter...

The typological framework will be operationalized in an experimental setting. Does providing designers while working on a design task with examples of product types, as opposed to product instances, result in new form concepts whose appearances embody the same 'Gestalt' determining features that make up for these types? And do these examples encourage designers to breakaway from their preconceived ideas, resulting in more innovative concepts? Or do they have just the opposite effect, directing designers to what is already existing, thus making it harder for them to come up with something new and original?

