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The embodied mind in relation to thinking about form development

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Abstract
This paper explores the notion that form development is fundamentally a process of the embodied mind. Traditional design methodology recommends that we should design by moving from concrete problem descriptions to abstract solution models. The abstract models are then developed towards concrete solutions via functional principles and principle structures. However, in the automobile industry concepts such as bone line and body are used when describing a car. We want to explore whether the designer is using some kind of metaphorical understanding instead of structural principles. A verbal protocol analysis showed that the designer uses his hand to understand product form while drawing it. This leads us to think that mental images interact in some way with action schema to play a part in the designers' apparently intuitive form-giving. This is in agreement with Lakoff and Johnson's proposal that metaphorical thinking is embodied. The results suggest that a closer look at embodied mind theory might be beneficial to understanding some of the apparently intuitive processes of the designer. We propose that such a study may provide us with ways of understanding and facilitating intuitive processes in design.

Keywords: form, tactility, thinking

1. Introduction
The word *intuition* is commonly used when explaining designers work. In general terms, "intuition" is the power or faculty of attaining direct knowledge or cognition without evidence of rational thought and inference [1]. It is a quick process. Sometimes it seems magical and is not necessarily a conscious process. To our knowledge, it is unexplainable, though several proposals exist. We will look at one of these before moving on to the question of how designers use intuition.

There are several directions of theoretical and neurological explanation of creativity and intuition. For our study a point of departure is Mumford and Caughron's [2] commentary to Vandervert et al. [3] which provides broad support for the proposal that creativity and intuition come from the basic motor properties in the brain. "*The cerebellum serves to abstract mental models reflecting patterns of activity and this forms the basis for language*

development and finally complex metaphorical representations. These models may be either forward (predictive in nature) or inverse (serving to produce automatic responses). Within the theory proposed by Vandervert et al., it is these forward mental models that provide the basis for creative thought in that multiple models, and multiple hypotheses, are activated in novel situations. The combination of these models, which in their view are primarily visual in nature, gives rise to new ideas. These new ideas are subject to both revision, and error-based testing, in formulating a creative idea [2]*."* Moreover, from trial-and-error we can identify what seems to be a general characteristic of so called intuitive environments or contexts of direct or unmediated engagement – or engaging *atmospheres* [4]. Applying Vandervert et al.'s model to design practice we see that technical function might be understood by the actions of the body. The designer can also work backward from the functions the product is supplying to the user and create representations of internal technical processes. The common term used in the technical development process related to the creation of new design is *form-giving*.

Form-giving in design could mean to shape or mould a particular mental model into a certain shape. In industry, it seems that the designer always associates form-giving with the *aesthetics*. The aesthetics element of form should also be explainable as embodied mental models, language and metaphor. Aesthetics here means designed aesthetics, the study of beauty related to effect of *gestalt* design on sensations [5]. Gestalt in design is defined as a totality of form experiences.

Finally, in order to relate something visual to the physical and emotional world, designers must transform a brief and background information into a new idea. The designer generates a gestalt by using language and then transforming it to physical activity such as human gestures or drawings or collages in order to produce a form, and the result of that should be to get a feel for its tactility, activity and experience. Moreover, repeated bodily interactions lead to the formation of image schemes determining the way we understand the world [6], and thus a new design is born.

We have shown that interpretation and understanding of form may stem from embodied mental models. The question is can we harness the embodied understanding of a product by facilitating it? We have conducted an experiment to this purpose, but before reporting on it we will briefly turn to traditional industrial design and engineering for signs of intuition or embodied thinking.

2. Thinking related to design activity

A few "Old Masters" of engineering design like Gerhard Pahl and Wolfgang Beitz, Vladimir Hubka, Eskild Tjalve, and Karlheinz Roth tried to make guidelines and catalogs related to the uses of engineering principle solutions (e.g., functional principles and principle structures) in order to assist designers in generating and developing an idea. However, the concept of intuition is not covered by them in great depth? Only Pahl and Beitz state that "…*good ideas are always scrutinized by the subconscious or preconscious in the light of expert knowledge, experience and the task in hand, and often the simple impetus resulting from the association of ideas suffices to force them into consciousness* [7]*."* It is apparent that the "Old Masters" way of thinking in the engineering design process is more toward *problem-solving* approaches. Problem-solving approaches are still being used by the designer in engineering design.

According to Simon the problem-solving process considers the design activity as a problem to solve [8]. For him, there are different variants, but all problem-solving process models can be described as a gap between an Observed State (S_o) and a Desired State (S_d), $S_o \neq S_d$ given a set of constraints. The procedure to apply in order to get to the desired state may be unknown. An observed state and a desired state may need to be refined and can change over time. Most of problem-solving process is related to three stages; (1) *Intelligence* (to understand an observed

state, a desired state, the constrains and define them), (2) *Design* (to generate solutions), and (3) *Selection* (to decide: (a) to redefine the problem which means going back to intelligence, (b) to refine or find new solutions which means going back to design, and (c) to choose one solution which involves finding evaluation criteria). However, problem-solving does not provide any tool or concepts for intuition.

Beside problem-solving, *synthesis* is also considered an apex of design activities. Synthesis is considered here as a compound activity as it involves search, exploration and discovery of design solutions, and the composition and integration of these solutions [9]. The definition of synthesizing in design activities is the result of abstracting and generating design concept(s) and structuring concepts to form a whole. This process may be modeled on two axes labeled abstract/concrete and undetailed/detailed (see [10, 11]). Modeling are activities used to represent the design solutions in terms of their function and/or structure so that their performance in terms of behavior can be analyzed and evaluated through testing in a real world of full-size or scale models, or simulated in possible worlds.

The designer views designing as a conversation with the materials and constraints conducted through the medium of drawing. The process is characterized as a reflective conversation with materials whose basic structure, seeing–moving–seeing, is an interaction of designing and discovery (see [12, 13]). For instance Schön states that *"…the designer sees what is there in some representation of a site, draws in relation to it, and sees what has been drawn, thereby informing further designing."* Lakoff and Johnson state that the most fundamental *metaphor* Descartes uses is the commonplace "Knowing is seeing" metaphor. There are two domains in this metaphor the visual domain and knowledge domain (see Table 1). The "Knowing is seeing" metaphor defines the core of a *folk theory* about how the mind works that is widely shared in our intellectual operations [14]. What Schön is saying is basically the same thing. Designers use visualization as a means of triggering new insights into the material they are working with. The insights may come from schemas or mental models, but they may also be analogies to something else.

Table 1. Knowing is seeing (from Lakoff and Johnson [14])

Visual domain		Knowledge domain
Object seen	→	Idea
Seeing an object clearly	→	Knowing an idea
Person who sees	→	Person who knows
Light	→	"Light" of reason
Visual focusing	→	Mental attention
Visual acuity	→	Intellectual acuity
Physical viewpoint	→	Mental viewpoint
Visual obstruction	→	Impediment to knowing

Designers use metaphor as a strategic approach during design activity. A metaphor is a figure of speech in which a word or phrase literally denoting one kind of object or idea is used in place of another to suggest a likeness or analogy between them. For example: the "conversation is war" metaphor or "time is money" metaphor. This method is employed visually as well, for instance in collages or semantic charts or as explanatory graphics in software user interface design.

The human body metaphor is generally used in the car industry. Designers often talk of "hard muscles" under "soft flesh," referring to the conceptual differentiation between kinds of underlying structure that state the characteristic shapes of the car from the merely cosmetic surface [15]. The concept of a solid structure under the surface of the car body is also called "a bone line" that defines the gestalt design of the car.

This way of thinking is opposite to the approaches from the "Old Masters" of engineering design. Their approaches are structured within concrete problem descriptions to abstract solution models. But yet, it seems that there are possibilities for using intuition as an alternative to engineering methodology.

3. Thinking with the embodied mind: is intuition an alternative to engineering methodology?

Since the "Old Masters" of engineering design did not give rise to a way of research related to the use of intuition during the design process, this may have limited the designer's way of thinking to associate ideas between the mind and the body. However, Lakoff and Johnson's statement about the notion of intuition in the design world seems to provide an option for another way of thinking. Even though intuition is *fuzzy* in current design practice, it still can be considered as an alternative to improve the design process.

In daily life, humans like to use the images in words such as 'beautiful' and 'ugly' to invoke moods in an object or a product. However, the psychological problems of focusing the image or feelings for a product are full of fuzziness and uncertainties. Traditionally, this mental recognition problem with high fuzziness is solved by the designer using his/her intuitive feeling as well as experience and inspiration from artistic work, and habit. However, designers from engineering always struggle to find the right methodology for this kind of fuzziness in design.

Based on the above reason, the study of intuition related to engineering methodology has attracted many engineering designers lately. Instead of quantitative methods which involve the measurement of quantity or amount, qualitative methods which involve the measurement of quality or kind have been used in design research [16]. Most engineering designers attempt to carry out design research focused on the combination of human physical activity and mental activity. They also explore a lot of possible ways of conducting experiments connected to the study about intuition. Some of them try to use existing instruments (equipment for measuring and recording data) from other disciplines [17] such as neurology in psychology, cognitive science, etc and matching those with the engineering instruments in order to study the language of intuition in design. Engineering methodology has failed to apply these tools to understand the cognitive-psychology and the neuro-psychology of the designer through experimentation. Instead, most of them discovered interesting findings during this kind of experimentation based on personal experience.

Figure 1. Indirect-direct continuum user interfaces (adapted from Hoff, Øritsland, and Bjørkli [18])

In order to identify the elements that constitute the "goodness" of personal experience in the language of intuition, we refer to an experiment carried out by Hoff, Øritsland, and Bjørkli [18] on indirect-direct continuum user interfaces (see Figure 1), in which indirect (or "second hand") information refers to activities that tap explicit reasoning; and direct (or "first hand") experience refers to perception-action cycles. Perception-action cycles again, refer to skill-based knowledge, in which "knowledge" refers to knowing *how*, as opposed to knowing *what.* The indirect interface requires the user to explicitly reason about information and interface,

one such example being the user interface information in the television. The domain of indirect interfaces represents a range of logical information, such as pictures, texts, and numbers that can be measured quantitatively. Meanwhile, the direct interface requires the user to employ skill-based, tacit knowledge, for example, the skill of riding a bicycle. The domain of the direct interfaces provides practical problems such as how to react and balance the body of human when riding a bicycle and it can be measured but no measurements directly convey the feeling you need to master bike riding. Qualitative methods come closest because they can communicate in expressive language.
Since intuition is related more to qualitative than quantitative qualities, we believe that the experiment related to the empirical study of intuitive form development in design should be conducted using qualitative method. The purpose is to see how perception-action cycles and explicit reasoning interact between subject, and mental representation.

4. Empirical study of intuitive form development

In order to empirically explore intuitive form development we conducted an experiment. A fourth year student from Norwegian University of Science and Technology (NTNU) (called hereafter the designer in short) kindly agreed to participate in this experiment. The controlled experiment was conducted based on observation using "Verbal protocol analysis."
Verbal protocol analysis (VPA) is a method of bringing out into the open some of the cognitive processes of designers. Of all the empirical, observational research methods for the analysis of design activity, VPA is the one that has received the most attention in recent years. Ericsson and Simon are the original disseminators of the VPA method [19]. The pros and cons, as well as the techniques for VPA, are described in-depth in their work. In terms of the validity of the experiment the verbalizations in the VPA indicate the inputs and outputs to the processes rather than the processes themselves. This is parallel to the research technique for design by Cross, Christiaans, and Dorst where they discuss the validity of VPA: The purpose of observation is to see any interaction between the mind and the body [20].

(a) Setup (b) Task

Figure 2. Setup and task of verbal protocol analysis

The basic strategy of VPA involves getting people who are doing something to verbalize their thoughts and feelings as they do whatever they are doing. VPA also maps how users describe themselves as interacting with objects. Both the verbalizing and interaction are rooted in language and cannot be separated from the respondents' linguistic use of objects in communication with others [21]. This is supported by Lakoff and Johnson, also Talmy and Regier, that the study of spatial-relation concepts within cognitive linguistics has revealed that there is a relatively small collection of primitive images schemas that structure systems of

spatial relations in the world's languages [22]. Their examples, without the full detail given above: part-whole, center-periphery, link, cycle, iteration, contract, adjacency, forced motion (e.g., pushing, pulling, propelling), support, balance, straight-curved, and near-far.

In this experiment, the studio setup (a) and task (b) are based on an artificial situation (see Figure 2). The designer has been provided with the brief of a project. The title of the project is "Design an Urban Scandinavian PDA (Personal digital assistant) adaptable to the needs of trades and profession."

In front of the subject, there are five standard posters [23] as references: (a) Image panel; (b) Influence panel; (c) Trend studies; (d) Product positioning; and (e) Market analysis.

Sketching is used as means of analyzing design activity (see [24]). This is because research related to design and thinking regards sketching as a means to stimulate creative thought [25].

We have conducted the experiment based on the synthesis of design activity (see the experiment by Lloyd, Lawson, and Scott [26]). There are three levels of abstractions that have been looked upon. The first level is the *abstract* level, followed by the *semi-concrete* level, and finally the *concrete* level. Abstract is the level when we question the choice and the orientation of the image elements; Semi-concrete is the level when we need to consider the type of form in which we format the image elements; and Concrete is the level where we make decisions that lead to a more detailed picture of the image developed so far. The process of design itself has different levels of abstraction. However, three levels are commonly in use and three are sufficient to get fruitful information in an experiment related to the design process.

During the designing process, from abstract to concrete level, the designer uses verbal expression as a way of communicating on what he is thinking. To identify relations between the designer's verbal expressions and body reactions, we analyzed the VPA, searching through the episodic data for signs of body use in the generation/discovery of design solutions (see Table 2). Analyzing the data, episodic intuition elements were discovered. We also identified examples of body reactions in episodic data, not linked to intuition, but still very important for the generation/discovery of the design solutions. The reaction of the body seems to automatically occur when the designer uses metaphor in explaining something visual. We found that few keywords based on verbal expression give a sign to body reaction. The words are: I think, then, erm, maybe, going, can be, fix, have, many, attachment, holding, could be, loose, need, numbers (like ten by fifteen), fold up, open up, I want, sliding, using, yeah, reminds, I like, but, seems, this idea, more, able, type, and whether.

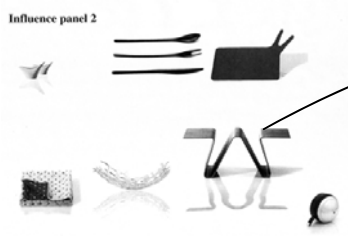
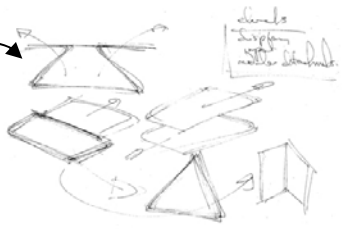
Table 2. Verbal expression and body reaction

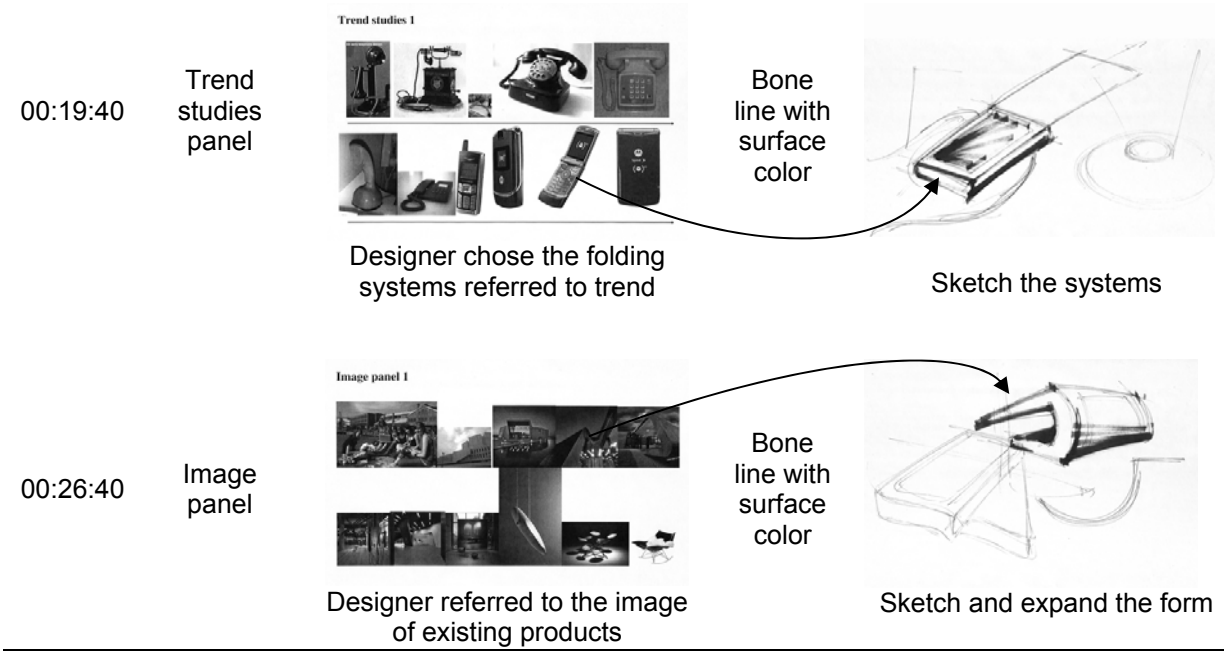
Protocol time	Episode of verbal expression	Sign of body reaction
00:01:23	…somewhere that *I think* need can be served existing PDA…	Eyes look at the poster
00:02:39	…specific profession and *then* take it back…	Hand move forward and backward
00:03:42	…*erm*…civil service…	Shaking the head
00:07:45	…*maybe* the regular function of PDA	Hand twist
00:09:35	…we *going* to have a device…we *have* main unit…we have a separate unit that *can be* attached…can *fix* the module idea…this *can be* connect everything *I think*	Left hand stand still at upright position
00:11:13	…we *have* many interfaces…and *many* input device…and the modular *attachment*	Hand point to the poster
00:12:31	…*holding* and *could be*…product screen	Left hand open
00:13:48	…a little bit too *loose* at the moment	Hand twist
00:15:48	…looking at this here…thinking about a device…fit	Hands open and close

	in the *need* of a rugged product…durable outer casing, to reveal the function something inside…I *need* the key elements of screen or display and modular *attachments*…	together
00:17:40	…*ten by fifteen*…*maybe*…*maybe* having a device…	Hand like holding something
00:18:14	…so, *I want* a device can *fold up*…*open up*…and can also support itself…independence of the user…	Hand open and close together and eyes look at the poster
00:19:25	…*sliding* component *maybe*…	Hand move forward and backward
00:19:36	…hand on device thinking…*using* one… hand…thinking tall and think versus short and fat…	Hand like holding something
00:23:38	…*yeah*…*I think* what Scandinavia is…less is more…	Hand move forward and backward
00.24:00	…that *reminds* me the red vessel…	Hand point to the poster
00:24:30	…*maybe* physical display…laser projection…display element…	Hand like holding something
00:30:43	…*I like* the shape…*but* I *need*…but it *seems* doesn't fix the function anyway…something *maybe more* aesthetics and *more* ergonomics *I think*…	Hand like holding something
00:32:02	…*I think* this *could be* a screw device…*maybe* not…I just thinking…I don't think…	Hand like holding something and finger move
00:34:22	…*this idea*…*I think*…	Hand like holding something
00:35:06	…*able* to *type* a data…	Hand like holding something and another hand like push a button
00:43:32	…I am thinking *whether* to *have* a screen…rectangle…extends all the way…two key button like a control function…	Hand like holding something

In the observations at the semi-concrete level, we found that the designer communicates with the information to define a concept. The designer is thinking and exploring possible design solutions to expand form variation. At the same time the designer looked at visual images in front of him to justify the final appearance of product. We found that the concept of a solid structure under the surface of the product body (also called "a bone line") defines the gestalt design of the product (see Table 3). This seems consistent with Monö's description of form as a part of gestalt, for him gestalt is an arrangement of parts which appear and function as a whole that is more than the sum of its parts [27].

Table 3. Image interaction design at the semi-concrete level

Protocol time	Episode			
	Interaction	Images	Features	Result
00:15:48	Influence panel	 Designer copied the existing form	Bone line	 Sketch the new form profile



Based on an in-depth study and detailed observation at the semi-concrete level (see Figure 3), we discovered that the designer frequently used an empty handed gesture to visualize the expected form.

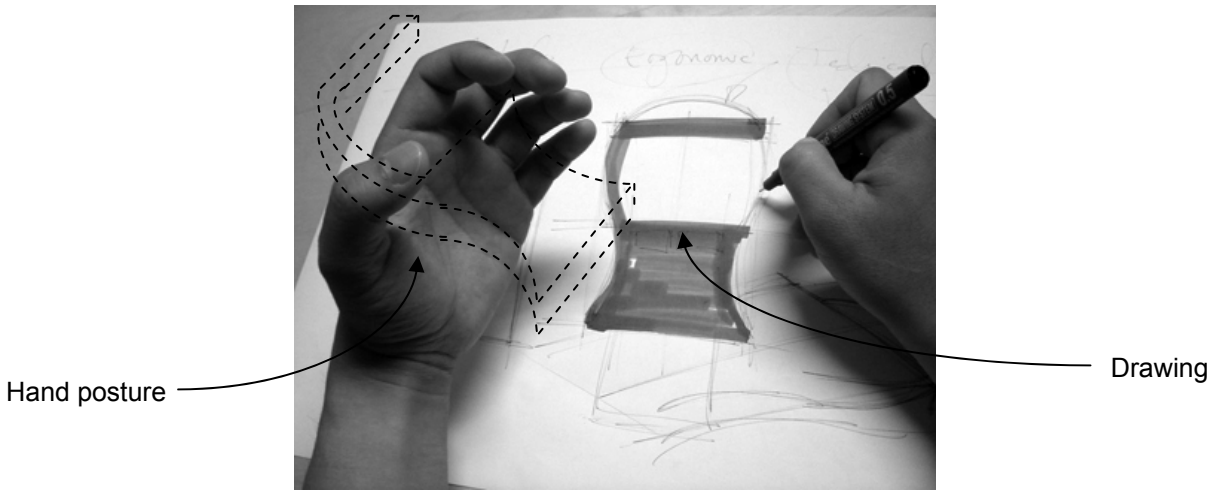


Figure 3. Designer use empty handed gestures to visualize the expected form at the semi-concrete level

In order to make the product explicit, at the concrete level, we also discovered that the designer continued with the use of hand posture activity in order to get a feeling for the tactility (responsiveness to stimulation of the sense of touch). Looking at the image, when the designer is drawing, the image is embodied through the movement of the hand to get the size of the imagery.

The imagery in question is embodied in the gestures that universally and automatically occur with speech. Speech and gesture occupy the same time slices when they share meanings and have the same relationships to context. It is a profound error to think of gesture as a code or "body language," separate from spoken language.

5. Conclusions

Based on the discussions and the empirical study of intuitive form development in design, we drew one major conclusion. The mind and the body of the designer play a role together in design. We observed that design is slow at the beginning of the abstract level and energetic at the semi-concrete level and concrete level with much development and exploration. At the semi-concrete level and the concrete level it is shown that the designer explores existing designs based on the posters in front of him by redrawing them. We hypothesize that this activity develops a stronger embodied understanding of the form. The designer uses his empty handed gestures to feel and describe form in relation to tactility. We can also hypothesize that other embodied forms, movements and tactile properties are being called on mentally, but are not visually apparent in this experiment.

The in-depth studies in this experiment show that the application of hand activity in design seems important to the designer in order to understand and visualize form related to the image in the mind. Similarly, in the automotive industry, designers use tape drawing or clay to balance a form and to adjust the proportion of the design. Based on our finding we assume that mental images interact with action schema and play a part in designers' apparently intuitive form-giving. It is also proven that the designer wants to feel the form of design in relation to the tactility. In addition to this finding being relevant to the manual process in design, in our opinion the finding also seems significant to the development of the Computer Aided Design (CAD) systems and software for the designer. When using CAD it might be beneficial for the designer to somehow feel the tactility of the form while designing.

This result is in agreement with Lakoff and Johnson's proposal that metaphorical thinking is embodied. In order to facilitate this form of thinking the design process should provide real size modeling with the body. Finally, for further research the results suggest that a closer look at the theory of embodied mind might be beneficial to understanding some of the apparently intuitive processes of the designer. This can be explored in further research on the embodied mind in the application of CAD. We propose that such studies may provide us with ways of understanding and facilitating intuitive processes in design.

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