Dimensions and Mechanisms of User Experience - from the Product Design Perspective

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Résumé : Ce document propose un modèle de l'expérience de l'utilisateur qui s'appuie sur plusieurs théories de la psychologie cognitive comme le "Wirkkreis" de Uexkuell, de la recherche en design comme les théories du Design Emotionnel, et du monde IHM comme le "Process Schema". Dans ce modèle on trouve les capteurs, la cognition et l'affect, et les réponses comme dimensions liées à l'utilisateur, les capteurs et les réponses du produit, ainsi que le contexte de l'utilisation et la temporalité de l'expérience. Ensemble, ces dimensions apportent une vue globale sur les mécanismes de l'expérience de l'utilisateur. Cela nous amène également à une discussion sur de nouveaux paradigmes dans le design produit. Tandis que le design produit classique s'est focalisé sur les formes, aujourd'hui le designer doit concevoir des changements dynamiques des fonctionnalités, de l'apparence, du comportement et des propriétés sensorielles. Il doit également anticiper le contexte de l'utilisation et des transformations dans l'expérience vécue dans le temps.

Mots clés : Expérience de l'utilisateur, Design Produit, perception humaine, Interaction Homme-Machine.

Abstract: This paper proposes a model of User Experience through user-product interaction based on various theories from cognitive science – like Uexkuell's Wirkkreis, design research – like Emotional Design theory, and Human-Computer Interaction – like the Process Schema. In the model appear sensor, cognition and affect, and response dimensions of the user, sensor and responses of the product, as well as the use context and the time dimensions. Together they build the User Experience. This brings new paradigms to product design. The classical form-giving has to evolve towards a holistic view on experience dimensions including changes of functionalities, appearance, behaviour and sensorial properties. Designers' awareness also needs to be directed to the anticipation of use scenarios and to potential shifts in user experiences over time.

Key words: User Experience, Product Design, human perception, Human-Computer Interaction.

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1. INTRODUCTION

Do you remember the first TV sets of the 1960ies? They were based on analogue technology and had a single functionality. Now look at the latest devices presented at tech fairs like CES. Today TV is digital and “smart”. The devices are multifunctional. You can access contents anytime, get additional information, comment contents over the social network, etc. With the arrival of the Internet of Objects the consumer can now adapt more and more products to his needs and desires. Toffler proposes to call him prosumer (Gerhardt 2008). As a consequence the role of the product designer too has to change. Not only is he asked to consolidate functional and aesthetical requirements. Today he has to design a User Experience.

The User Experience has therefore become a great topic of interest for researchers and companies. Researchers in cognitive psychology were the first to look at the human perception of objects (Gibson 1986). With the arrival of personal computers the domain of human-computer interaction emerged with the goal to improve the usability of graphical interfaces (Forlizzi and Ford 2000). In the design domain, researchers of “Kansei Engineering” (Tomico et al. 2008) in Asia were the first to anticipate the emotions, sensations and semantics conveyed by a product design. At the beginning of the new century, “Emotional Design” emerged as a research domain in the Western world (Desmet 2002; Norman 2004). It focuses on the emotional value of products. Furthermore researchers of “Affective Engineering” investigate the sensorial experience evoked by materials and textures (Salvia et al. 2010). Today more and more researchers integrate the findings of these various domains under the keyword User Experience (Hassenzahl 2011; Locher, Overbeeke, and Wensveen 2009) as an enclosing topic.

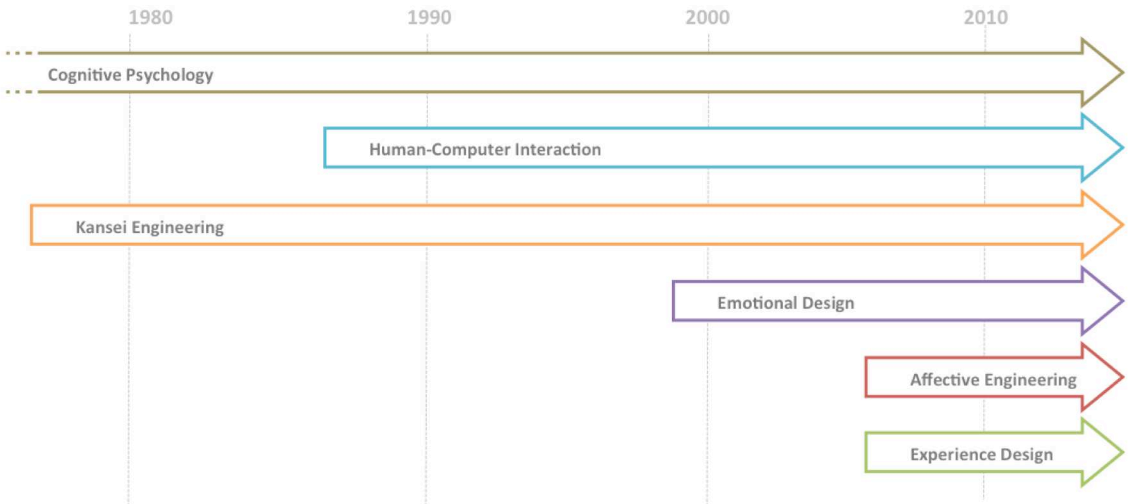


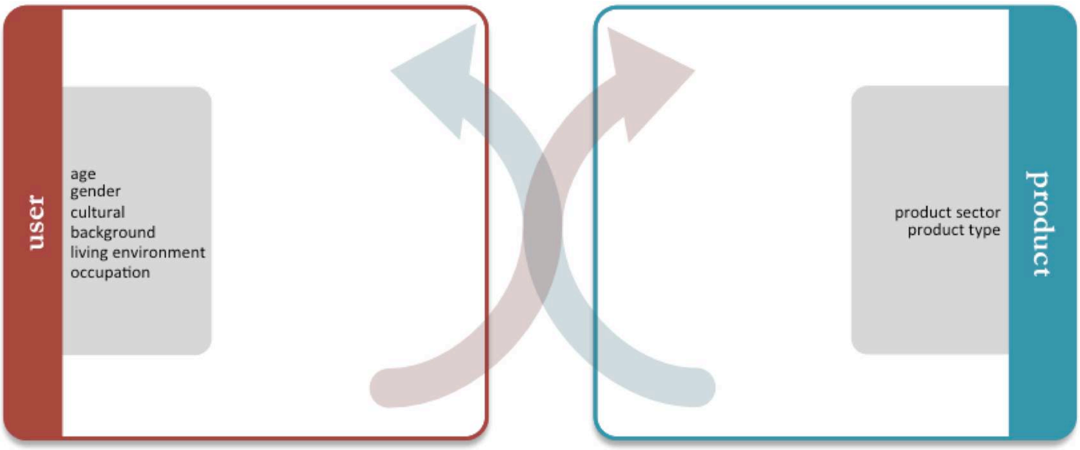
Image 1: Evolution of the user-product related research domains.

User Experience is a multidimensional quality. A review of research papers revealed affect/emotion, enjoyment/fun, aesthetics/appeal, hedonic quality, engagement/flow, motivation, enchantment, frustration, etc. as contents of current User Experience research (Bargas-Avila and Hornbæk 2011). This list shows that there is still an incoherence of the terms and a lack of hierarchy and structure when we talk about User Experience.

User Experience is defined as “a person’s perceptions and responses that result from the use or anticipated use of a product, system or service” (ISO 9241-210). In this definition appear the human and the product with their respective perceptive and responsive capabilities. These capabilities can be addressed by product and interaction design (Djajadiningrat et al. 2004). In this paper we seek to consolidate the insights from the mentioned research domains. We look at dimensions and mechanisms of human perception and define the range of product dimensions that can evoke a reaction of the user. The use context and the temporality of experience are added as a third and fourth layer. Together this leads us to a proposition of a model of dimensions and mechanisms of User Experience.

2. BASICS OF USER-PRODUCT INTERACTION

A user is a human who is targeted to utilise a product. Distinguishing dimensions that might influence his comportment towards a specific product are his age and gender (Crilly, Moultrie, and Clarkson 2004), cultural background, living environment (Locher, Overbeeke, and Wensveen 2009), and education/occupation. A product on the other side is a specific type of object or interface or service that can be classed in a certain sector like automobile, alimentation, cosmetics, etc. (Krippendorff 2005).



The principles of how users experience products are equivalent to the human perception of the environment – a mechanism that has been investigated by Cognitive Psychology, Neuroscience, Sociology, Semiotics, and Philosophy for more than a century. From it we can draw conclusions on how humans perceive and interact with products.

One of the first models on human perception was Uexkuell's 'Scheme for a Circular Feedback' (Wirkkreis). According to it, the nervous system interacts with the environment through sensory inputs and motor outputs. Organisms hold *receptors to sense* changes of the *indicator* (the environment) in order to anticipate and coordinate actions that help them to fulfil their goals (e.g. nutrition, reproduction, belonging). These *sensory receptors* constantly adapt their state upon interaction with the environment or object. Inside the nervous system, the information circulates between *sensors* (the mark organ) and *effectors* (the action organ). One can model the path information takes inside the nervous system as perception loops through the memory. Each internal loop serves a different function: measurement, computation, prediction, evaluation, and action. The memory contents continually modify themselves as a response to new experiences. Sensed patterns are compared to previous patterns and templates are created or altered. The nervous system then determines which actions to take in response to the sensed information (Axelrod 1973; Cariani 2001). The action organs (e.g. muscles) act as *effectors* that can alter the state of the *indicator* (the environment or the object they interact with). The human learns to understand an unfamiliar object by interacting with it (Russell 2003).

Gibson enriched this model through the so-called affordances approach. Thereupon we do not perceive characteristics of the environment but rather opportunities for action, so called affordances, like climb-ability, pull-ability, etc. (Gibson 1986). When people perceive their surroundings they recognise coherent patterns of objects or events that have a meaning to them (Russell 2003). For UX design this means visual properties like form or colour do not become stimuli just by themselves but through the affordance they communicate. Perception is based on successive reception and actions (Lenay 2006).

3. DIMENSIONS OF HUMAN PERCEPTION

Sensing, cognition and affect, and response are embedded in neural discharge activities. Neuroscientists do not yet agree on the brain mechanism involved (Cariani 2001; Bonnardel 2012) but there exist various models that describe each of these dimensions. In the following we therefore look at dimensions of human perception based on the 3 levels defined by Uexkuell: the *human senses*, the *human cognition and affect*, and the *human responses*.

HUMAN SENSES

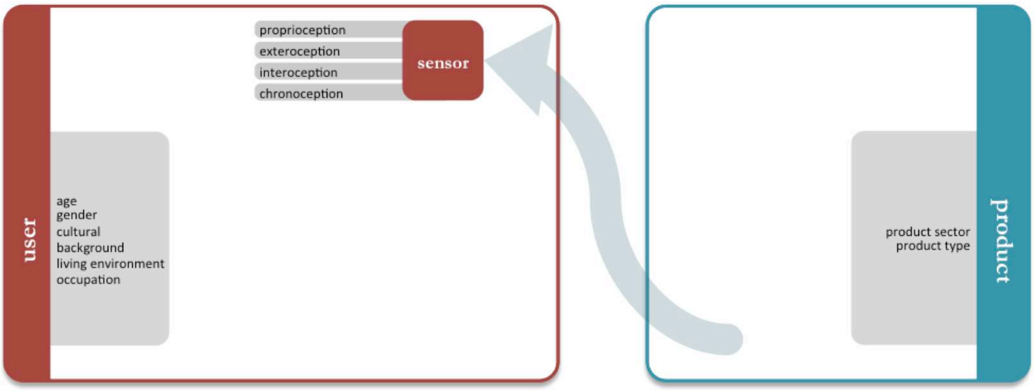
In order to perceive their surrounding, humans dispose of a limited range of physiological sensors. They can be classified into exteroceptive, proprioceptive, interoceptive senses and chronoception (LaMuth 2011). The following table gives an overview and definition of each type of human sensor.

Table 1: Types of human senses.

Sense	Definition
EXTEROCEPTIVE	Capture stimuli that are external to the organism (Oxford dictionary), in order to keep him aware of the environmental changes. They are *visual* (eyes/ophthalmoception), *auditory* (ears and bones/audioception), *gustatory* (tongue with taste buds/gustaoception), *olfactory* (nose/olfacoception), and *somesthetic*. The somesthetic senses form a complex system able to sense *heat or cold* (thermoreceptors), *pain* (nociceptors), *pressure* (pacinian corpuscles), and *touch* (mechanoreceptors) (Amsel 2005).

PROPRIOCEPTIVE	Arise from the spatial body orientation. They include the sense of *balance* (vestibular input from the inner ear/equilibrioception), *position* (limb and joint afferents/ stretch receptors), and *movement* (muscles for kinesthesioception).
INTEROCEPTIVE	Relate to stimuli that are produced within the organism from the *visceral, digestive,* and *autonomic* systems to secure bodily functions. They work through *chemoreceptors* that regulate hunger, thirst, body temperature, blood pressure, and sexual behaviour.
CHRONOCEPTION	Humans also have limited capabilities to sense of time. However the perception of event duration is subjective and variable. There is no direct sensor for time, it is mostly reconstructed from other sensed information (Tangient LLC 2013).

Humans are also capable of cross-sensory transfers. For example people who lose sight can partially substitute the visual sense with enhanced auditory and tactile senses. Furthermore sensory substitution devices can be employed as a new means to acquire the non accessible information to compensate the loss of one sense (Bach-y-Rita and W. Kercel 2003; Lenay et al. 2003). Synaesthesia is a phenomenon "in which stimulation of one sensory modality causes unusual experiences in a second, unstimulated modality" (Hubbard and Ramachandran 2005) like letters or numbers that are associated with colours (grapheme-colour synaesthesia), sounds that induce colours (Grossenbacher and Lovelace 2001), or lexical-gustatory synaesthesia where sounds evoke a taste (Ward and Simner 2003). Real synaesthesia happens involuntary and concerns about 4 % of the population (Simner et al. 2006).



This is a brief overview on the type of information a human is able to capture. So far products address only few of these capabilities. The focus lies on the visual and auditory information and an emerging trend are tactile and olfactory stimuli. To address a wide spectrum of sensors holds a high potential for Experience Design. For example, when touch becomes part of design considerations, the texture but also the felt temperature of the material or the weight of the object are dimensions that humans can sense and appreciate.

HUMAN COGNITION & AFFECT

Once stimulus information has been captured by the human senses, it enters the perception of the human that prepares responses to this stimulus. The perception involves two closely related mechanisms: cognition and affect. Cognition enables the human to understand his environment, affect allows him to judge what he perceives (Bonnardel 2012). Cognitive events are essentially related to an object/a situation/something. On the contrary, humans experience emotional episodes induced by an object but also independently of any stimulus (Russell 2003). To this day neuroscientists are still discordant whether both are distinct or if cognition is included in the affective process. They agree that affect has a cognitive component (Bonnardel 2012; Lane et al. 2000; Russell 2003; Scherer 2004). Khalid suggests that humans treat stimuli parallel on the affective and on the cognitive level (Khalid 2006). Affect is intuitive and experiential. Cognition is the analytical, rational part of information treatment. It creates lasting knowledge and accords meanings.

To understand cognitive and affective mechanisms of human perception is important for User Experience Design. Several cognitive and affective components are intentionally or unintentionally addressed by a product or interface. The better we understand these mechanisms the more consciously we can design objects for the desired cognitive and affective response.

One possibility to model the process of cognition is the Schema Model that describes how human's process new information to make sense of it. According to this theory any new information is compared to patterns that have been used in the past. By doing so, old patterns are reinforced or modified. At the beginning stands a stimulus that holds different types of information on several cases at a specific instance in time (e.g. the current condition of an object property like the fill level of a glass). The information also has a known source. The human has built schemas to interpret information. The information is processed in the following way: When a message is received, the human seeks first to find an already available interpretation of this case. If that exits, he will verify if the new information is in accordance with the old interpretation. If that is the case this interpretation will be reinforced and the behaviour is equivalent. If the new information does not fit old interpretations, he first questions the credibility of the source. If it is low, he will keep the old interpretation. If the source credibility is high, he will amend the old interpretation. If no interpretation exists so far, other schemas are sought to help with the interpretation. The human will try one schema after another starting with the schemas that are the easiest to reach / that have served often. If he finds a satisfying interpretation with the help of a schema, the applied schema will become more easily accessible and the source credibility will be upgraded. If no schema can be found to interpret the information, the source credibility will be downgraded and no interpretation is done (Axelrod 1973).

Cognitive processes link the external stimuli information with the brain (the user's knowledge and memories) in order to reach an interpretation of the stimuli on their semantic and aesthetic character (Hassenzahl 2003). They also allow the evaluation based on the user's concerns/values/preferences and lead to the prediction, planning, and coordination of outputs (Cariani 2001).

Contrary to cognitive processes the affective part of information processing is still little understood and models are more based on folk than on scientific concepts (Russell 2003). Some researchers call it affect, others emotions. Yet emotions are only one part of affect. Wundt was the first to propose an affect model. It is based on three continuous dimensions: pleasant-unpleasant (valence), tension-relaxation (tension) and excitement-calm (arousal) (Wilhelm Max Wundt 1914). Studies suggest that unpleasant stimuli are more arousing than pleasant ones (Bradley and Lang 2000). It has also been shown that events that are accompanied by strong arousal are better remembered. However this seems to be stronger for negative than for positive valence (Kensinger 2009). As a synthesis of the types of affects defined by Scherer (2004) and Russell (2003), the following phenomena can be distinguished:

Table 2: Types of human affect.

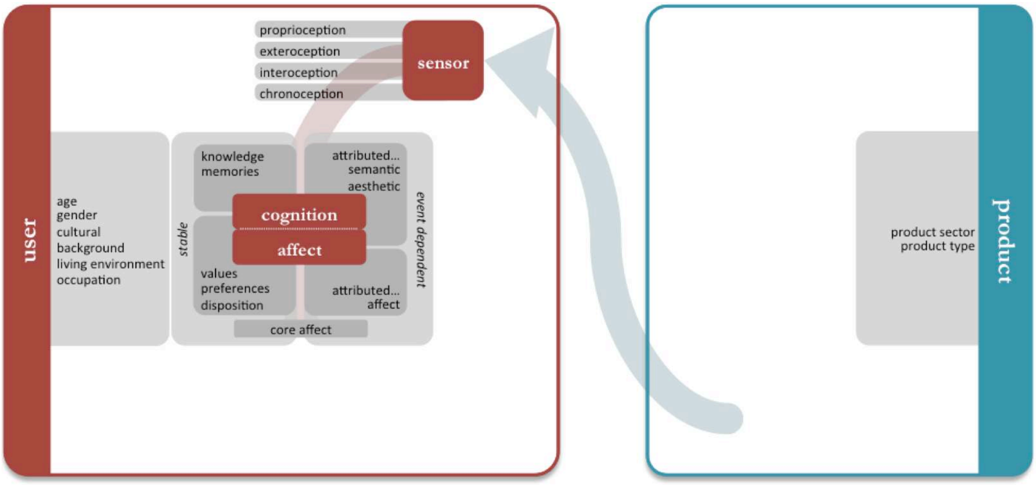
Affect type	Definition
CORE AFFECT (MOOD)	Diffuse affect states of low intensity, usually rather long lasting, independent of an object/person/event (irritable, depressed, cheerful, buoyant, etc.).
ATTRIBUTED AFFECT	Affect attributed to an object/person/event.
UTILITARIAN EMOTIONS	Brief episodes of synchronised response "of all or most of the five organismic subsystems" to an external or internal stimulus event that is relevant to the organism, personal goals and bodily needs (fear, anger, sadness, joy, disgust, etc.).
AESTHETIC EMOTIONS	Brief episodes experienced through evaluations of sensorial stimuli on their intrinsic qualities, irrespective of bodily needs, current goals or social concerns, addressed to a cause like a piece of art, a design, music, etc. (being full of wonder, admiration, fascination, ecstasy, harmony, rapture, etc.).
PREFERENCES	Stable evaluative judgements on the pleasantness of a stimulus (like/dislike, positive/negative).
CONCERNS/VALUES	Enduring beliefs or predispositions towards an object or a person (loving, hating, desiring, rejecting, etc.). They are based on values that are "desirable, trans-situational goals […] that serve as guiding principles in people's lives" (Schwartz and Sagiv 1995).
AFFECT DISPOSITIONS	Stable personality traits that lead a person to frequently experience certain moods and to react with similar emotions and behaviours on certain types of objects, persons or events (nervous, anxious, reckless, jealous, etc.).

Affect dispositions, concerns/values and preferences are rather stable elements of human affect. They slowly evolve over the person's lifetime as a result of interaction with the environment (Desmet and Hekkert 2007). Core affect can last for a day, some days or even weeks. Attributed affect alters instantly with each new stimulus. There are long-lasting affect components that influence the experienced temporary core affect and attributed affect. As such affect dispositions, concerns/values and preferences are always present, but only addressed once there is an external stimulus to be evaluated. Contrary to that, humans always experience some state of core affect, even if they are not conscious about it. Core affect is an intrinsic state of the human. It describes a mood or a lasting state. At any time anybody is able to define his core affect state.

Products can be an external cause that alters core affect (Russell 2003). When the human perceives an external stimulus, an emotional episode starts. Emotional episodes are evoked by the affective quality of the stimulus. The affective quality of a stimulus can be perceived as pleasant or unpleasant, and activating or deactivating. The perception of the affective quality of a stimulus does not necessarily change the core affect. Both can be experienced at the same time even in a non-congruent way. Somebody who feels depressed will find a joke funny, and yet still feel sad. An affective quality that is perceived by the human becomes an *attributed affect* (Russell 2003). Scherer's utilitarian and aesthetic emotions can be considered as two different types of *attributed affect*.

Design evaluations should try to distinguish between *attributed affect* and *core affect* in order to draw relevant conclusions. People are able to evaluate the *affective quality* of objects or events even without being in the real situation (Russell 2003). However, *core affect* can only be measured in the real interaction. Otherwise there is the risk of misinterpretation caused by misattribution or mood-congruent judgement. Misattribution means that the *core affect* evoked by one source is mistakenly attributed to the wrong object (Schwarz and Clore 1983). Mood-congruent judgement has for effect that a person who is feeling happy processes more positive information of the stimulus and therefore rates it more positively than she would if she was in a gloomy mood (Bower and Forgas 2012). Negative moods are more easily attributed to an external cause than positive moods (Schwarz and Clore 1983).

To evaluate the affective quality of a product, it might therefore be useful to first measure the *core affect* of the test person, and then the quality the person attributes to the product. When we downgrade the *attributed affect* for persons with a highly positive *core affect* and upgrade it for those with a negative *core affect* we might get an overall idea of the actual affective quality of the product. It is also relevant to understand the values, preferences and disposition of a person to interpret her evaluation of a design (Bouchard et al. 2009).



Now that we have seen human senses and cognitive and affective treatment of stimulus information, we take a look at the effector end of human perception.

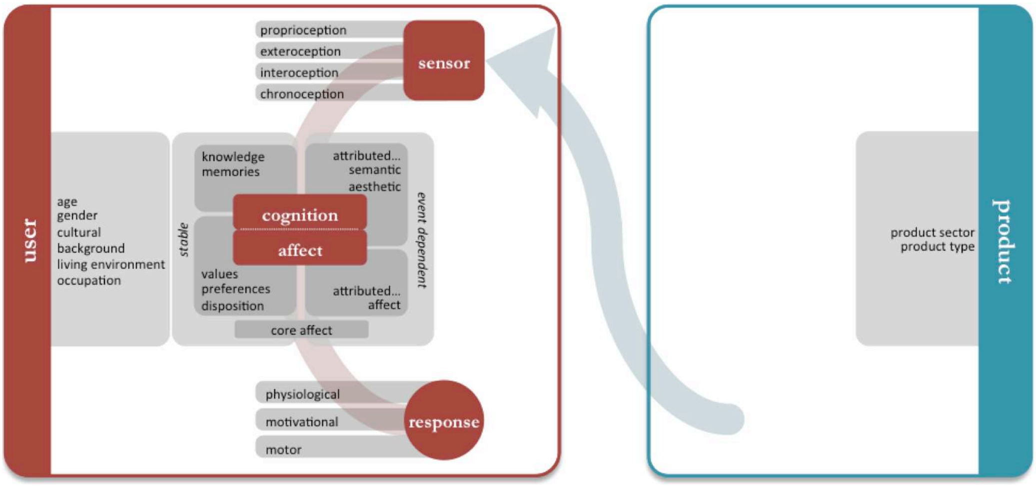
HUMAN RESPONSES

Human responses constitute the third element of the human percept-action loop. There are three different response types *physiological/somatic, motor, motivational* (Scherer 2004; Scherer 2005). Motor and motivational responses are related to controllable events. Physiological responses can also be of uncontrollable nature.

Table 3: Types of human responses.

Response type	Definition
PHYSIOLOGICAL EFFECTS bodily symptoms	Responses of the human metabolism. Symptoms are temperature sensations as a consequence of blood circulation (red cheeks, cold hands, pale face), respiratory accelerations/decelerations, cardiovascular accelerations/decelerations, muscle tension (weak limbs, trembling, relaxing), constriction in internal organs (stomach ache, lump in the throat), and body fluids (transpiration, salvia, odorant) (Scherer 2004). These responses happen when events appear that disturb the on-going body state. They have for purpose to set the human body in the condition necessary to cope with the situation. An augmented blood rate for example prepares the body to run away from an aggressor. They can also be an unconscious means of communication.
MOTOR EFFECTS facial, gestural, posture, vocal (action)	Occur on three different body parts: the limbs (gestural, postural), the face (mimic), and the speech organs (vocal). Gestures, postures, mimics and voice are more or less controllable means of human communication that enable the human to visually and audibly show the outsider in which state the situation put them and how they will react (Scherer 2004). Values that distinguish motor effects are the speed, the amplitude, the frequency/rhythm, pauses, and patterns. The meanings of facial expressions have been subject of research in psychology from Darwin, to Paul Ekman, and Nico H. Frijda.
MOTIVATIONAL EFFECTS action tendencies and readiness (behaviour)	Stable action tendencies towards a specific object or situation (Scherer 2005), in general approach or withdrawal (Russell 2003). Become visible in human comportment. The person directs her attention to the subject, like somebody who always buys a specific brand or acts with consciousness on the environmental impact of his behaviour.

Human responses that users show to products can be observed or measured through observation techniques like eye tracking or through physiological measurements like EEG, GSR etc. (Kim 2011). They therefore provide rather objective data to researchers. However, even though these responses are the result of cognitive and affective judgements, "no specific action or action tendency is produced by or is necessary for a specific emotion" (Russell 2003). That means an observed behaviour does not represent one specific affect felt by the person. The researchers need to look at the totality of responses and the person's subjective self-evaluations in order to draw conclusions on her user experience.



This first part introduced the dimensions of human perception. We saw that humans dispose of a wide range of sensors that can capture stimulus information. Here lies a first entry point for original ideas to design for User Experience. We also found how stimulus information is processed through the interplay of human cognition and affect. To address certain cognitive responses, designers can work on a semantic expression of a product. Designs can also transport a certain affective quality. But the designer cannot control all individual dimensions of human perception. Somebody's current mood or previous memories are outside of the design scope. Nevertheless, this points at a huge potential for intelligent products that can adapt their properties to the user's individual affective disposition and knowledge. Finally the range of human responses was introduced. They can be of physiological, behavioural or motivational nature. A design that causes reactions on each of these three levels is likely to be more engaging than one that only addresses one level. Product developers should envision ways to enable their products to not only react on behavioural but also on physiological responses. In order to do so, the designer needs to know which product dimensions he can potentially influence through his design. This is therefore the topic of the next section.

4. PRODUCT DIMENSIONS

Hassenzahl assigns four major functions to products: 1. Enable people to manipulate their environment, 2. Stimulate personal development, 3. Express identity, and 4. Evoke memories (Hassenzahl 2003). To do so, products must possess certain properties that facilitate these functions. Classical dimensions of product design are functionalities, form, colour, material, texture, etc. They will not be further discussed here since it seems more interesting to look at properties that enable the product to interact with the environment or the user. Today products too come with sensors that facilitate intelligent responses to user responses. Some product properties can also be designed with a flexible behaviour. An analogy can therefore be drawn with the human perceptive system. In the following, potential sensory and responsive capabilities of products will be presented.

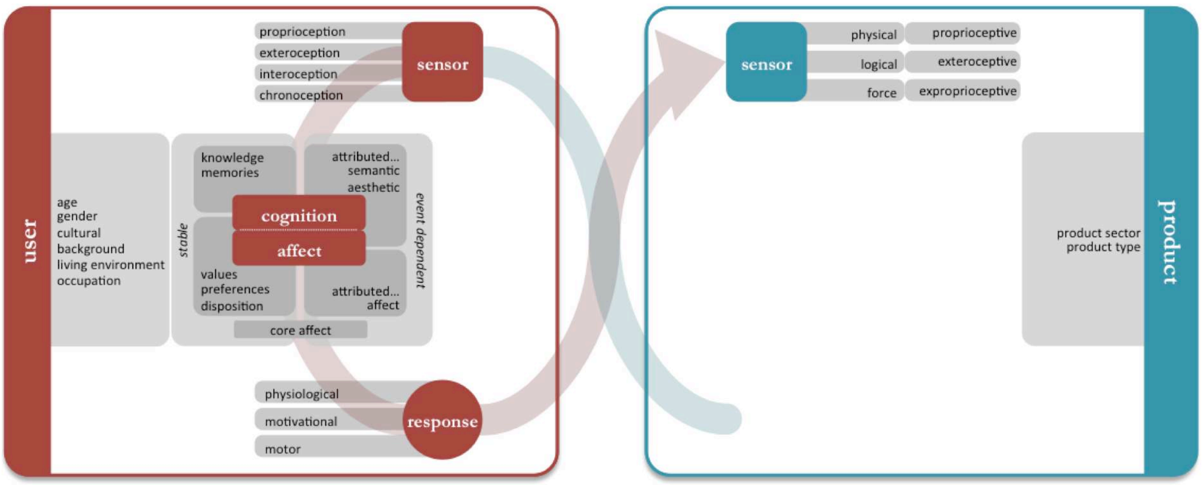
PRODUCT SENSORS

In order to react to user inputs, products need to be capable of perceiving human responses. Classic consumer products (furniture or decoration, or the external parts of industrial designs like car chassis, telephone housing, etc.) are usually not equipped with sensors. Nowadays there are more and more products that show a dynamic reaction to user inputs through tangible or graphic user interfaces. These products come equipped with a great variety of sensors, depending on the product type and behavioural objective. Such sensors can be classified into the following types (Robotworx 2013):

Table 4: Types of sensors for consumer products.

Sensors categories	Sensors types	Definition
Physical Sensors	Active sensors	Emits some form of energy, Ultrasonic, laser, infrared
	Passive sensors	Receive energy, example: a camera
Logical Sensors		Supplies robot with a percept from the physical sensor
Proprioceptive Sensors		Monitor self-maintenance, control internal status. For battery monitoring, heat monitoring. Examples: Global Positioning System (GPS), Inertial Navigation System (INS), Shaft/rotary Encoder, Compass, Inclinometer
Exteroceptive Sensors	Contact Sensors	Emit a signal on physical contact Measure the interaction force and torque Tactile sensors, conductivity (linear, circular, discontinued)
	Range Sensors	Measure distance to an object Two principles: time-of-flight and triangulation (reflection, sonar, capacity)
	Vision Sensors	Extracting, characterizing and interpreting visual information
Exproprioceptive Sensors		Combination of proprioceptive and exteroceptive monitoring; measure the relative position through directional sensors, measure difference between internal and external heart. Examples: panning sonar sensors, force sensors.
Force Sensors		Measure torque or force or weight

Today product designers have access to a wide range of sensors and actuators (for behavioural response) that are easy to employ in the phases of rapid prototyping – nearly like a pen for sketching or some 3D software for modelling. There are for example the Arduino kits (Arduino 2012) or Phidgets (Phidgets 2012) with MAX/MSP, Processing or Adobe Flash with ActionScript that allow designers to model interactive behaviour coupled with sensing technology. These techniques find their way into design education and once design graduates master them, they will enrich the interactivity of products and with it the User Experience (Helm, Aprile, and Keyson 2008).



PRODUCT RESPONSES

All externally perceivable product dimensions are potential stimuli for the user. Products can be characterised through *concrete* dimensions of lower order and *abstract* dimensions of higher order (Snelders 2003). Concrete dimensions include the properties of function, behaviour, appearance and sensorial properties. They are designed to evoke abstract dimensions on a pragmatic and a hedonic level (Hassenzahl 2003). The term pragmatic refers to the product utility and usability. A purely pragmatic product simply fulfils a behavioural goal, e.g. cutting paper for a pair of scissors. The hedonic side addresses the user's emotions, values, and memories. A purely hedonic product, like a family photo, might have no pragmatic value but can be very important to the person. While the perception of abstract properties might differ strongly between users, the perception of concrete properties is essentially the same between persons of different background. In user-centred design, abstract properties define the design objective. The product designer then materialises this objective through the concrete properties (Snelders 2003).

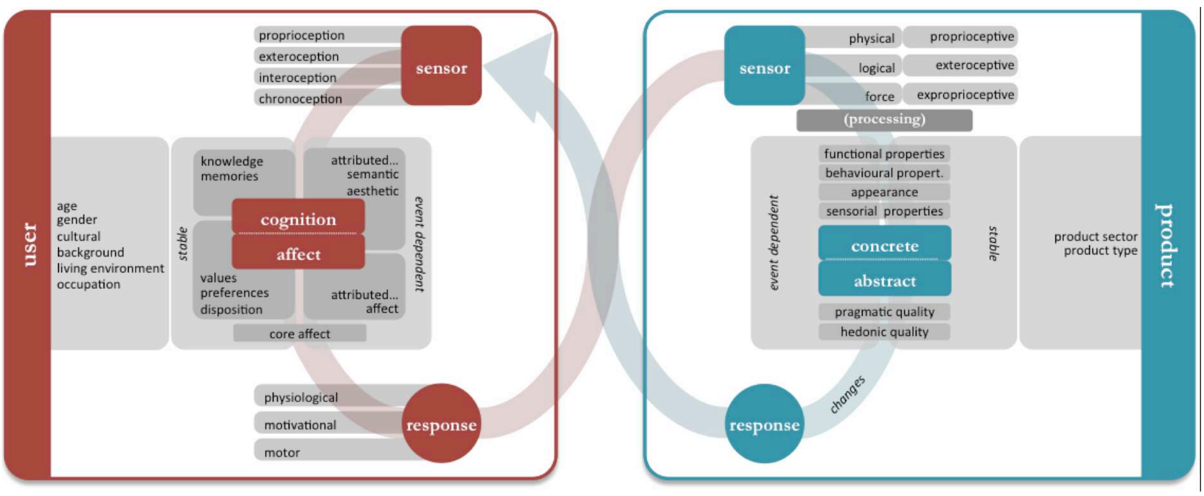
Classical product designs stimulate the user through their functions and appearance. Today intelligent technologies have found their way into consumer products. More and more products are connected to a network, pro-active and capable of adaption to events (Ross and Wensveen 2010). The design of intelligent products goes beyond traditional product design and can even be independent of physical materials (Y. Lim, Lee, and Lee 2009). To conceive interactive products, designers require "a new language of form that incorporates the dynamics of behavior" (Ross and Wensveen 2010).

Dynamic product responses mean that the product adapts its properties to the situation. It may for example alter the orientation of some of its components (like Nabaztag moving his ears) or its colour (e.g. clicked links). These changes can be instantaneously or follow a fixed pattern (Lin and Cheng 2011; Y. Lim, Lee, and Lee 2009). Shape change is a specific behaviour that waits to be exploited by Product Designers. These can be changes of orientation, form, volume, texture, viscosity, spatial changes, as well as addition or subtraction of elements or changes of permeability (Kirkegaard Rasmussen et al. 2012). Related to it are spatial distribution and motion patterns that can express complex meanings that people interpret on a social dimension (approaching, avoiding, etc.) (Mutlu et al. 2006).

Table 5: Possibilities of dynamic responses for products.

Dimension	Property	Behaviour
Material	(Depending on the material)	Elasticity, colour, temperature, conductivity…(Ashby and Johnson 2010)
Colour		Hue, saturation, lightness
Texture	Visual texture Tactile texture	Smoothness, transparency…
Illumination		Intensity, colour, movement pattern, fade pattern
Sound (Özcan 2008)	Volume	Increase or decrease
	Timbre	Change type
	Pitch	Increase or decrease
	Melody / pattern	Change in a pattern or randomly
	Spatiality (source)	Orientation change
Form		Geometrically defined Free-forms Adapt to human dimensions (ergonomic)
	Body volume	Increase or decrease
Orientation		Between two states or seamlessly 360°, on 3 spatial axes
Permeability		Binary or seamlessly From complete permeability to impermeable
Spatial distribution		of product elements in the available space systematic (meaningful) or random way; the product itsself can change its position in the room/space
Components		Can be added/subtracted
Functionality		Can change when the purpose is distorted, e.g. a bottle becomes a vase, a chair used as a ladder
Language style		Casual / formal style Natural / artificial style (Blanchy 2010)

Products are constituted of a wide range of design dimensions. They define the product appearance as well as its behaviour. To this day product design is often seen as something static. But products can be equipped for dynamic responses. Designers have the possibility to explore for example form changes thanks to flexible materials, or spatiality and motion changes on graphic interfaces in order to communicate with the user or to adapt the behaviour to the use context. To design such adaptive behaviour, product designers need knowledge about the different types of human or environmental responses that a product can capture if equipped with the corresponding sensors and they should exploit the possibilities of the here presented response types.

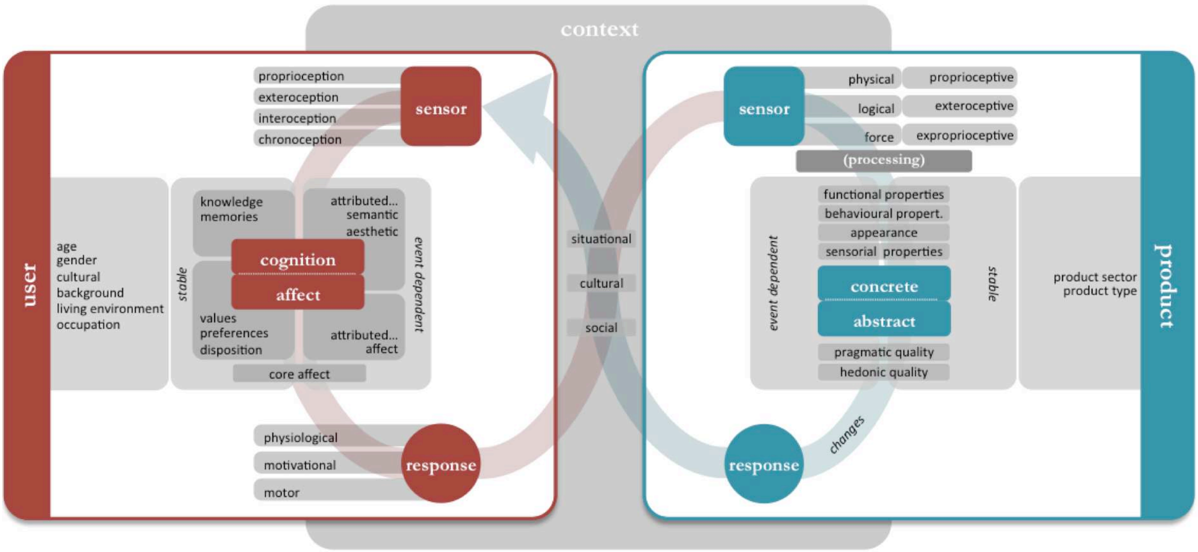


5. THE EXPERIENCE CONTEXT

Any user experience is embedded in a certain situation. The context partly influences which properties the human or product sensors capture. The context might also influence the treatment of the stimulus information. The externalities that influence the User Experience with a product are formed by *situational, cultural* and *social* factors (Krippendorff 2005; Crilly, Moultrie, and Clarkson 2004; Forlizzi and Ford 2000; Locher, Overbeeke, and Wensveen 2009). The following table gives an overview on potential context dimensions:

Table 6: Interaction context dimensions.

Cultural factors/references	Similar products/brands/activities
	Clichés/stereotypes
	Trends/fashions/tastes/conventions
Situational factors	Viewing time
	Related products/features/things
	Place
	Time
	Event/activity
Social factors	

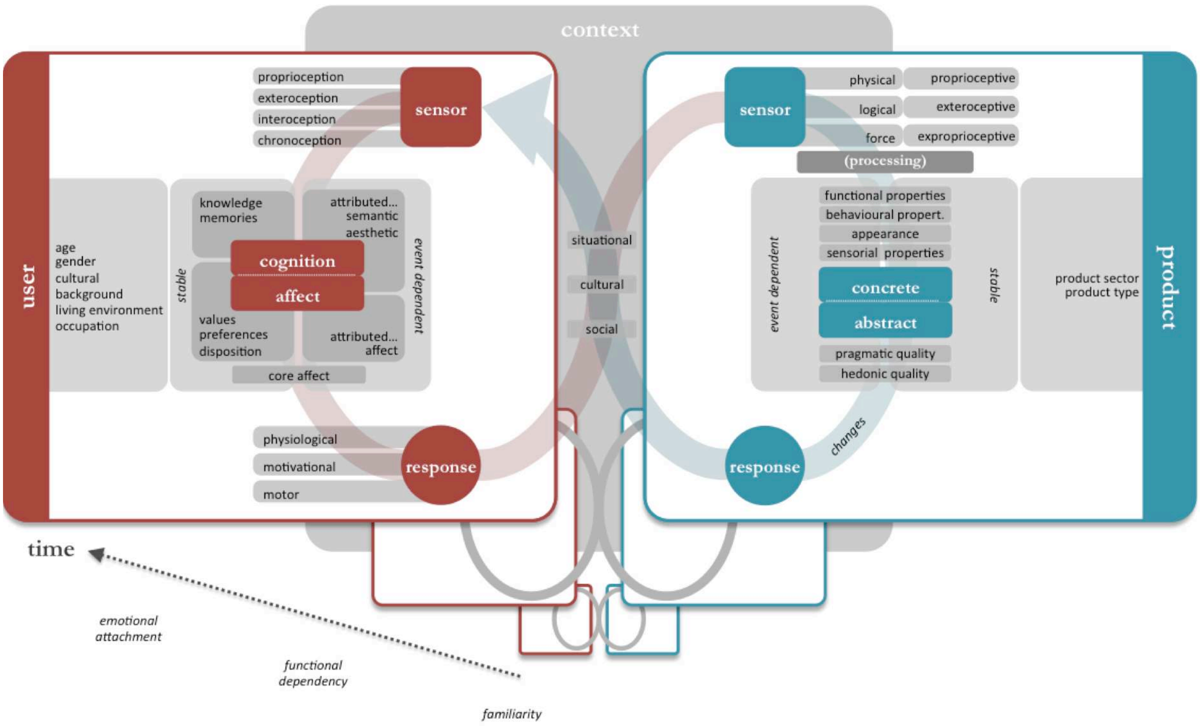


6. TEMPORALITY OF EXPERIENCE

A final dimension that has been identified as an important factor of User Experience is time. Some experience like a surprise can only be lived once while other experiences grow over various use episodes. Hassenzahl therefore demands a "longitudinal approach" to User Experience design. He distinguishes between a micro (an hour of usage), meso (a few weeks of usage), and macro (years of usage) perspective on the User Experience with a product (Hassenzahl 2010). Roto et al. identified four types of User Experience over time: the anticipated UX (before usage), the momentary UX (during usage), the episodic UX (after usage), and the cumulative UX (multiple periods of usage over time) (Roto et al. 2011). From the product design point of view, there are two different types of temporality that can be effectively shaped by the designer: The use sequence of the actual interaction and certain aspects of the cumulative UX of the product usage over a long time.

Use sequences: A dynamically changing product is conceived as a continuous cycle of sensing and response on the human and on the product side. The human as well as the artefact are both capable of sensing inputs, processing this data, and responding with distinct behaviour (output actions). The data circulates between the human and the artefact and is transformed (Krippendorff 2005). The emotions felt by the user change over the different interaction steps (Lin and Cheng 2011).

Long-term UX: An interactive product might show reoccurring response patterns to user actions, but the user might respond differently after a while. Surprise can only be triggered once. Excitement changes into comfort once the user gets familiar with the product. Even when the product disappears from his sight, the memory of it can still trigger emotions (Norman 2004). Karapanos et al. undertook a long-term study with iPhone users from the intention of purchase until a few months of usage. They proved a shift in User Experience over time. During the initial orientation phase, the experience is mainly formed by stimulation and learnability. This leads to a certain *familiarity* with the product. In the following incorporation phase usefulness and long-term usability are important. A *functional dependency* of the user on the product appears. Finally the user can enter the phase of identification where he shows an *emotional attachment* to the product (Karapanos et al. 2009).



Besides human perception of product appearance and behaviour responses as well as product sensing means, context and temporality could be identified as two additional dimension of User Experience. Designers should anticipate the use context and the temporal course of use sequences as well as the potential development of the User Experience over the time of product use during the early design process.

7. CONCLUSION: FROM PRODUCT DESIGN TO UX DESIGN

For centuries, people have created and refined products. A common understanding of Gestalt laws or colour harmonies has developed within and beyond cultural boarders. Designers have long been occupied with form-giving of material products. While engineers dealt with functions, components and performance, product designers were asked to work on form, colour, and semantic (Djajadiningrat et al. 2004). Now microcontrollers have considerably enriched the capabilities of everyday products to process the user input and to respond with discrete output behaviour (Y. Lim and Kim 2011) and therefore to adapt their behaviour to the context of use and user actions (Djajadiningrat et al. 2004).

This brought new opportunities as well as challenges to product designers. The user perception of interactive products goes far beyond form-giving. Interaction impacts the affective experience (Schuster Smith 2008). Hassenzahl illustrates this with the example of the Philips Wake-Up Light: "…it substantially changes the way one wakes up. It changes the experience. The object itself, its form, is rather unremarkable" (Hassenzahl, Eckoldt, and Thielsch 2009).

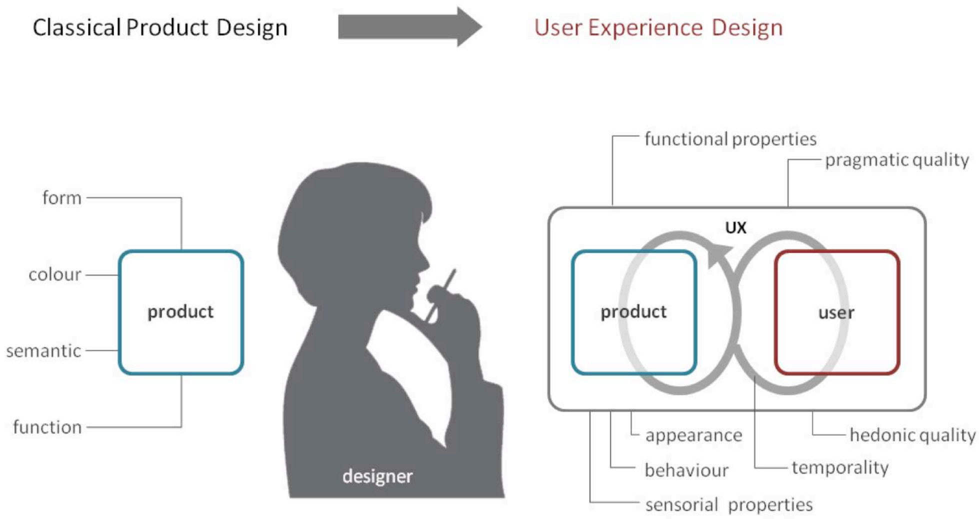


Image 2: Dimensions of concept generation in Classical Product Design (left) and as a vision for User Experience Design (right).

Even though people might not expect great emotional stimulation from all products, it cannot be neglected that each artefact causes a reaction in its user – appeal, indifference or rejection. Thus, all goods and services made for consumers have to respond to some kind of physiological, psychological or social human need (D. Lim 2003). Today form-giving is only one of various issues that product design needs to address. This literature review showed us that User Experience results from the interplay of a wide range of concrete (form, colour, semantic, function) and abstract (affective and sensorial quality, semantic quality, aesthetic quality) product dimensions, together with the perception of the target user, the context in which he encounters the product and the temporality of experience. Today's challenge for product developers is to switch their focus from material product dimensions to a holistic view of User Experience.

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