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DESIGN FOR INTUITIVE USE - TESTING IMAGE SCHEMA THEORY FOR USER INTERFACE DESIGN

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ABSTRACT

Demand for interactive products that are intuitive to use is high. Intuitive use in this paper is understood as the subconscious application of prior knowledge by the user. This definition is explicated by a continuum model of prior knowledge. Theories from several disciplines of application are surveyed whether they can contribute to the field of 'Design for Intuitive Use'. Two sets of requirements are posed against which candidate theories have to be validated: (1) the claims the theory makes about intuitive use must be shown to be valid within the context of user interface design, and (2) the application of the theory has to support the user interface design process. Image schema theory which draws on knowledge on the sensorimotor stage of the knowledge continuum was put to the test by using rigorous psychological experimentation and by analysing user interfaces in different domains of application. These analyses showed that the application of image schema theory as a design language may be a powerful tool for the evaluation and improvement phases of a human-centred design process. By collecting the results of these analyses in an online catalogue, designers are provided with a tool that helps them with producing design solutions. Ongoing studies are investigating whether image schemas are also useful for the early phases of the design process such as requirements gathering. Although the studies are not finished yet it is concluded that the image schema approach offers value to and insight in designing user interfaces that are intuitive to use.

Keywords: human-technology interaction, usability, intuitive use, user interface design, theory testing

1 THE DEMAND FOR INTUITIVE USE

Products are often advertised with slogans like "Intuitive interface designed to make searching fast and easy", "Keypad improves intuitive use for drive controls", and "Intuitive interface allows end users to use without help". The increasing *technological* convergence of products makes 'intuitive use' one of the unique selling propositions on competitive markets. Going from the marketing to the design department one might ask: Why should product designers bother with 'Design for Intuitive Use'?

Generally there is a trend towards enhancing products' ease of use (instead of just adding more features). One factor is the increasing ubiquity of interactive computer applications. As a consequence, too many different devices accrue in the environment of users, so that the time available for learning and using each device is greatly reduced. Enhanced possibilities for personalisation and extra functionality contribute to an increasing complexity of products. Think for instance of the multifunctionality of mobile phones that have been extended with cameras, media players, and organizer software. On the mass consumer market 'Design for Intuitive Use' is of critical value. User groups become larger and more heterogeneous with respect to age, experience, and cultural background. Virtually everyone has to be able to use ticket and cash machines, interactive TV sets, or in-car driver assistant systems. Also, on the market for investment goods, where the total cost of ownership of products usually plays a greater role, issues like user productivity, training and support costs, ergonomics, and security become more and more important. Here, a shift from hardware to software interfaces can be observed that goes along with a higher level of abstraction to the use of products. Human-machine interaction increasingly becomes mediated by computers. Technology which is intuitive to use is thought to help with reducing cost and increasing user satisfaction.

"Intuitive use" currently is a buzzword, more, however, than the related concept of "usability" [1]. While *usability* is relevant for virtually any interactive product, *intuitive use* especially is required for beginners, rare users, diverse user groups or users that have no time or are unwilling to learn about operating a product. Expert users, on the other hand, want to achieve results quickly and are happy with learning powerful functionality that is controlled by written command code, keyboard shortcuts or transaction codes. Pure intuitive use could stand in the way of their need for speedy performance and may even be seen as a hindrance. Intuitive use is to be seen as a subconcept of the general concept of usability (see below).

Having sketched the concept, the next section of the paper delivers a more clear-cut definition of intuitive use. The main focus of the paper is on how theories from various disciplines may be investigated to assess whether they facilitate building products that are intuitive to use and support the user interface design process. This methodology is applied to investigating a promising theory: image schema theory.

2 DEFINITION OF INTUITIVE USE

When setting intuitive use as a design goal, first an understanding has to be developed about the meaning of the concept. This question of definition has been answered by starting with an empirical approach – asking users, developers and usability experts - and by transforming this into a theoretical framework for research on intuitive use [2],[3]. The resulting definition served as the common ground for further discussion of the topic with colleagues from different backgrounds of theory and application: engineering, industrial design, computer science, linguistics, and psychology [4], [5]: *A technical system is intuitively usable if the users' subconscious application of prior knowledge leads to effective interaction.* Two concepts of this definition need further explanation. One is the notion of 'prior knowledge'; the other is 'subconscious application'.

2.1 Continuum of knowledge

Prior knowledge may stem from different sources. These knowledge sources can be classified along a continuum from *innate* knowledge, knowledge from embodied interaction with the physical world (*sensorimotor*), and *culture* to professional areas of *expertise*. On each of the latter three levels there might be specialist knowledge about using respective *tools* and technologies (Figure 1).

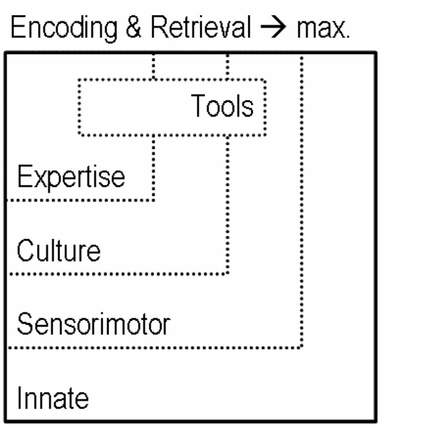

Figure 1. Continuum of knowledge in intuitive interaction

The first, and lowest, level of the continuum consists of *innate* knowledge that is 'acquired' through the activation of genes or during the prenatal stage of development. Generally this is what reflexes or instinctive behaviour draw upon. Purists will see this as the only valid level of knowledge when talking about intuitive interaction, because it assures universal applicability and subconscious processing.

The next level is *sensorimotor*. It consists of general knowledge, which is acquired very early in childhood and is from then on used continuously through interaction with the world. Children learn for example to differentiate faces; they learn about gravitation; they build up concepts for speed and animation. Scientific notions like affordances [6] and the later discussed image schemas [7] are residing at this level of knowledge.

The next level is about knowledge specific to the *culture* an individual lives in. Underlying knowledge can vary considerably between cultures and may influence how people approach technology. This, for

instance, touches the realm of values (e.g. what constitutes a taboo), the styles of visual communication (cf. Japanese manga vs. American comics), but also (partly implicit) knowledge about daily matters like the usual means of transportation (e.g. busses, trains, or bicycles) or the prevalent form of energy supply (e.g. by a public power line or by burning wood for heating).
The most specific level of knowledge is *expertise*, i.e. specialist knowledge acquired in one's profession, for example as a mechanical engineer, an air traffic controller, or a physician; and in hobbies (e.g. modelling, online-gaming, or serving as a fire-fighter).
Across the sensorimotor, culture and expertise levels of knowledge, knowledge about *tools* can also be distinguished. Tool knowledge seems to be an important reference when designing user interfaces. Tools at the sensorimotor level are primitive tools like sticks for extending one's reach and stones used as weights. Tools at the culture level are those commonly used by human beings, like ball point pens for writing, pocket lamps for lighting, or cell phones for communication. At the last stage there is knowledge acquired from using tools in one's area of expertise, for example CAD tools, enterprise resource planning (ERP) systems, or CNC machines. Even within the same domain of expertise (e.g. engineering design) there may be differing knowledge on the tool level, depending on the kind of tools used (e.g. CATIA vs. Pro/ENGINEER).
The continuum of knowledge has an inherent dimensionality. The frequency of encoding and retrieval of knowledge increases from the top to the bottom of the continuum. The further towards the top level of the continuum, the higher the degree of specialization of knowledge and the smaller the potential number of users possessing this knowledge. But still, on each level of the knowledge continuum 'intuitive use' (according to the above definition) can be assigned – as long as it is *subconsciously* applied by users.

2.2 Subconscious application of prior knowledge

In his model of human data-processing Rasmussen [8] distinguishes between a subconscious (analogue and parallel) processor and a conscious (symbolic and sequential) processor. According to this model perception is mapped subconsciously to the actual goal states of the user and to his (also subconscious) dynamic world model stored in long term memory. This forms the basis of an efficient control of physical actions. On the other hand, when there is a mismatch between perception and world model, the conscious processor is activated. The conscious processor works by controlling attention and is limited by the capacities of working memory and sequential processing.
The application of knowledge may be subconscious from the beginning on (as with reflexes) or may have become subconscious due to frequent exposure and reaction to stimuli in the environment: the more frequent the encoding and retrieval was in the past, the more likely it is that memorised knowledge is applied without awareness by the user. Knowledge at the expertise level is acquired relatively late in life and is (over the life span) not as frequently used as knowledge from the culture or sensorimotor level. As learning theory suggests, knowledge from the lower levels of the continuum is therefore more likely to be applied subconsciously than knowledge from the upper levels. If the subconscious application of knowledge is a precondition for intuitive use, it will be more likely to see intuitive interaction involving knowledge at the lower levels of the continuum. Limiting 'intuitive interaction' to the lower levels of the knowledge continuum does have further advantages:

- The further down in the continuum, the larger and more heterogeneous the user groups that can be reached. While almost everyone will have a concept of 'verticality' (sensorimotor level), not everyone understands the CATIA software package (tool/expertise level).
- Instead of being required to analyse the prior knowledge of the specific target user group, designers might simply refer to rules generated from findings about the general structure of human knowledge (i.e. general human knowledge on the sensorimotor level).
- Extremely frequent encoding and retrieval events lead to a higher robustness of information processing. In situations of high mental workload and stress a fall-back on lower stages of the knowledge continuum will occur. This will be especially important for the design of systems with high safety demands (e.g. control of an aircraft or of a nuclear power plant).
- Subconscious processing of user interface elements in general means less workload on the cognitive processing capacity. Thus more cognitive resources will be available for solving the work task at hand instead of wasting time and mental effort on figuring out how a piece of technology works.

3 THEORETICAL ACCOUNTS OF INTUITIVE PHENOMENA

Where in theory are criteria to be found that support Design for Intuitive Use? A survey of candidate theories was conducted and one theory – the theory of image schemas – was singled out to evaluate its value for the user interface design process. The following paragraphs give a brief overview of the theories considered and introduce the theory of image schemas.

3.1 Theories considered

The above definition of intuitive use allows the formulation of search spaces for the derivation and formulation of guidelines. The following fields of application were identified as making use of phenomena featuring 'subconscious processing of prior knowledge'. They mainly refer to lower, more general levels of the knowledge continuum: innate, sensorimotor and culture.

Quite well known theoretical accounts of intuitive phenomena can be found in the disciplines of ergonomics and usability (like the notions of compatibility and population stereotypes [9], [10]). Promising theories describing subconscious processing phenomena stem from psychology (i.e. gestalt theory [11], the concept of affordances [1], [6], theories of implicit learning and implicit memory [12], heuristics and biases in judgment and decision making [13], and the relatively new field of embodied cognition [14]). While some of them can be readily transferred for use in user interface design (see [2] for a derived set of guidelines), others are still elusive in regard to application in user interfaces and have yet to be investigated empirically.

Other disciplines able to contribute to Design for Intuitive Use are certainly visual design and the arts. What is known there can well be exploited for designing intuitive interaction (cf. the effects perspective, colour, contrast, texture, form, and arrangement have on the intuitivity of the user interface). More speculative are the findings from the discipline of marketing [15], [16]. Fields like advertising, packaging design, event marketing including storytelling techniques, and sales psychology clearly target consumers' intuitive processing according to the above definition. But the problem is: it is not yet known how to use these findings for user interface design. It is not known how dependent these findings are on the context and product sold, or whether the results can be generalised. More research, in particular theory-building, may help to transfer these findings to the field of user interface design.

The contributions from visual design, the arts, and marketing can be especially useful since these disciplines – like Design for Intuitive Use – are looking at the phenomenological side of things. They are concerned with how people interpret and experience artefacts and how their perceptions and interpretations influence their decisions on whether to buy and how to use the products they are encountering. One especially interesting field in this respect is cognitive linguistics. Its theory of image schemata, a kind of "cognitive universals", and on conceptual metaphors will be discussed in more detail in the following section.

3.2 A promising candidate: image schema theory

What are image schemas?

Image schemas can be placed on the sensorimotor level of the knowledge continuum (Figure 1). They are abstract representations of recurring dynamic patterns of bodily interactions that structure the way humans understand the world [7]. The CONTAINER schema, for example, forms the basis of the daily experience with cars, housings, boxes, tea pots, cups, etc. A CONTAINER is characterized by an inside, an outside, and a boundary between them (Note: image schemas are usually written in small caps).

Image schemas are much more abstract than images. They are schematic in nature and, as they capture the structural contours of sensory-motor experience, they are not just symbols. According to the theory they exist beneath conscious awareness. They integrate information from multiple modalities and could thus be represented visually, haptically, kinesthetically or acoustically.

Depending on the author, about 30 to 40 such image schemas are distinguished [7], [17]. Table 1 organizes them into seven groups. Their universal character, their - in the course of life - extremely frequent encoding in and retrieval from memory and their subconscious processing makes them interesting for using them as patterns for designing user interfaces. A LEFT-RIGHT schema (along with an UP-DOWN schema), for example, may be represented by a mini joystick on toy car's remote control.

When the joystick is moved leftwards, the toy car turns left. A rightward move with the joystick lets the toy car turn right (simple physical mapping).

Table 1. List of image schemas, grouped by similarity

Group	Image Schemas
BASIC SCHEMAS	SUBSTANCE, OBJECT
SPACE	UP-DOWN, LEFT-RIGHT, NEAR-FAR, FRONT-BACK, CENTER-PERIPHERY , CONTACT, PATH, SCALE
CONTAINMENT	CONTAINER, IN-OUT, CONTENT, FULL-EMPTY, SURFACE
MULTIPLICITY	MERGING, COLLECTION, SPLITTING, PART-WHOLE, COUNT-MASS, LINK, MATCHING
PROCESS	ITERATION, CYCLE
FORCE	DIVERSION, COUNTERFORCE, RESTRAINT REMOVAL, RESISTANCE, ATTRACTION, COMPULSION, BLOCKAGE, BALANCE, MOMENTUM, ENABLEMENT
ATTRIBUTE	HEAVY-LIGHT, DARK-BRIGHT, BIG-SMALL, WARM-COLD, STRONG-WEAK, STRAIGHT, SMOOTH - ROUGH

Metaphorical Extensions

Although image schemas describe human sensorimotor experiences with the physical world, their actual strength lies in their metaphorical extension for structuring abstract concepts [7], [18]. Linguistic analyses have shown that image schemas can serve as source domains of countless metaphors, e.g. [19]. As language reflects thought, image schemas and their metaphorical extensions should also be working in non-linguistic reasoning. In fact there is growing evidence of this coming from the field of cognitive psychology [20], [21], [22], [23], [24], [25], [26]. If image schemas and their metaphorical extensions are common primitives of thought (as the theorists claim and the empirical evidence suggests), then they might be exploited for designing intuitive use. The following section will give an example of the UP-DOWN schema.

An example: the UP-DOWN schema

The UP-DOWN schema, together with the spatial schemas LEFT-RIGHT and FRONT-BACK, has been used in virtually all user interfaces, at least for physical mappings. UP-DOWN can be used either in a static fashion (i.e. placing interface elements above or below another) or in a dynamic fashion (moving objects vertically, e.g. with the mouse). Physical UP-DOWN placement and movements of objects may lead to analogous placement and movements in virtual space. One example is moving the cursor UP and DOWN in the menu of a mobile phone by moving a small joystick on the phone UP and DOWN.
Linguistic analysis points to metaphorical extensions of the UP-DOWN schema to conceptualize abstract domains like

- Quantity, as in: The number of books printed each year is going *up*. Sales *rose* last year. The number of errors made is incredibly *low*. He is *under*age. (MORE IS UP - LESS IS DOWN)
- Quality, as in: Things are looking *up*. This is a *high-quality* product. We hit a *peak* last year, but it's been *downhill* ever since. (GOOD IS UP - BAD IS DOWN)
- Status, as in: She'll *rise* to the top. He has little *upward* mobility. He's at the *bottom* of the social hierarchy. (HIGH STATUS IS UP - LOW STATUS IS DOWN)
- Control, as in: I have control *over* her. I am *on top* of the situation. His power is on the *decline*. (HAVING CONTROL OR FORCE IS UP - BEING SUBJECT TO CONTROL OR FORCE IS DOWN)
- Virtue, as in: She is *upright*. That would be *beneath* me. He is *high* minded. That was a *low-down* thing to do. (VIRTUE IS UP – DEPRAVITY IS DOWN)
- Happiness, as in: I'm feeling *up*. That *boosted* my spirits. He is really *down* these days. I'm *depressed*. (HAPPY IS UP - SAD IS DOWN)
- Other dichotomies like HEALTH AND LIFE ARE UP - SICKNESS AND DEATH ARE DOWN, CONSCIOUS IS UP – UNCONSCIOUS IS DOWN, RATIONAL IS UP – EMOTIONAL IS DOWN, UNKNOWN IS UP – KNOWN IS DOWN (see [18], pp. 14-21 for more examples).

These metaphorical extensions can be transferred to user interfaces: moving a virtual slider upwards might be used to increase the cutting speed when controlling a CNC machine (using the metaphor

MORE IS UP) or to indicate the evaluation results of different products (using GOOD IS UP). Similarly, the joystick of the mobile phone described above may also be used for controlling the intensity of the illumination of the display by moving the joystick either upwards for a brighter light or downwards for dimming the light (using the metaphor MORE IS UP).

4 TESTING THEORIES FOR USER INTERFACE DESIGN: REQUIREMENTS

If theories are to be successful in the area of Design for Intuitive Use they must fulfil two sets of requirements: (1) the claims the theory makes about intuitive use must be shown to be valid within the context of user interface design, and (2) the application of the theory has to support the user interface design process. Details of these requirements will be discussed in the next sections.

4.1 The theory makes valid claims

First it must be checked whether applying these theories to user interface design results in effective interaction by subconscious application of prior knowledge (cf. the above definition of intuitive use). How can this be measured? Classic usability measures are concerned with effectiveness, efficiency, and satisfaction of use (see Table 2, [1], [27], [28]). *Effectiveness*, according to the ISO 9241-11, is the accuracy and completeness with which users achieve certain goals. Indicators of effectiveness include error rates or the quality of goal achievement. *Efficiency* is the relation between the effectiveness and the resources expended in achieving the goals. Indicators of resource spending include task completion time, learning time, mental workload, number of mouse clicks or key presses, material consumed, and derived measures such as financial cost (labour cost, equipment cost, training cost). *Satisfaction* is the users' comfort with and positive attitudes towards the use of the system. Users' satisfaction can be measured by attitude rating scales or preference ratings in a questionnaire.

Table 2. Usability measures and their application to Design for Intuitive Use

Usability measures (ISO 9241-11)	Indicators	Relevance for Design for Intuitive Use
Effectiveness (the accuracy and completeness with which users achieve certain goals)	error rates	Yes (effective interaction is part of the definition of intuitive use)
	quality of goal achievement	
	proportion of users achieving goal	
Efficiency (the relation between the effectiveness and the resources expended in achieving the goals)	users' mental effort	Yes (points to subconscious use of prior knowledge)
	users' physical effort	No (no direct correlation with intuitive use according to the above definition)[1]
	task completion time	
	cost	
Satisfaction (the users' comfort with and positive attitudes towards the use of the system)	attitudes	Yes (users should be satisfied with using technology)
	preferences	
	subjective effectiveness and efficiency	
	experienced stress and strain	

How do these measures relate to intuitive interaction? Effectiveness is inherent in the definition of intuitive use, so these indicators will apply. Of the various efficiency measures only one is interesting for the field of intuitive use: mental workload. Subconscious application of prior knowledge will only affect mental efficiency since it removes workload from the conscious cognitive processor. Cognitive workload can be measured either by objective or by subjective means. Objective measures include physiological measures like heart rate variability or, under special circumstances (see below), also response times. Subjective measures are obtained from questionnaires that ask people how difficult they find a task like the Subjective Mental Effort Questionnaire (SMEQ) and the NASA Task Load Index (TLX), [27]. The other efficiency indicators are not important for intuitive use: mouse clicks,

[1] This means that the probabilities are equal for intuitive use to, e.g., enhance, decrease or not change the amount of physical effort needed by the user (e.g. number of mouse-clicks) for using a specific user interface. More clicks, i.e. increased physical effort, might in certain cases support intuitive use.

overall task completion time etc. Satisfaction also must be measured when validating candidate theories for intuitive interaction. A questionnaire for measuring satisfaction in the context of intuitive use, named Evalint, has been introduced by Mohs et al. [2].

4.2 Applying the theory supports the design process

Theories not only must be valid, but for designers they also have to be applicable within an established user interface design process [29]. This means that the theory or the guidelines derived from the theory should be beneficial throughout several phases of the design process. According to [29] this fulfils the requirements "be integrated in the existing design environment" and "support compatibility of methods". For example, the ISO 13407 ("Human-centred design processes for interactive systems", [30]) defines the following design phases: plan, specify context of use, specify requirements, produce design solutions, and evaluate designs. However, being applicable to the phases of the design process is not enough. The effort of applying a methodology must be compared to its value. This is what in [29] is referred to as "be easy to use", "solve problems 'in no time'", and "produce convincing results for complex problems". An example: The proposed guideline for building interfaces that are intuitive to use might be to first thoroughly analyze the prior knowledge of each user and then design interfaces that can be personalised by the user or vendor. However, this would not be feasible because the cost would be prohibitively high compared to the achieved value. Other requirements to design methodologies, according to [29] are: "require as little effort for learning and training as possible", "support teamwork as well as individual work", and "structure work sequence".

5 TESTING IMAGE SCHEMA THEORY FOR USER INTERFACE DESIGN

The following sections apply these requirements to test image schema theory.

5.1 Does the theory make valid claims?

The first question to be asked is: can designers build better products in terms of effectiveness, (mental) efficiency, and user satisfaction, when they apply the claims of image schema theory to user interface design? This question can only be answered empirically. The procedure taken consists of three steps: (1) the identification of suitable metaphorical extensions of image schemata, (2) the design of user interface elements laid out either consistently or inconsistently with the metaphor (3) the design and execution of experiments with users and the measurement of usability variables.

For the first two experiments the UP-DOWN schema was chosen because of its especially rich metaphorical extensions (see above). In user interfaces the UP-DOWN schema may be represented by vertically arranged buttons (used in experiment 1, Figure 2) or vertical sliders (used in experiment 2, Figure 3). Invariably in user interfaces, image schemas are superimposed by others. The realisation of the UP-DOWN schema with vertical buttons also introduces the CONTAINER schema via the buttons. Likewise, using a slider introduces the SCALE schema to the user interface. In the following the set-up of both experiments is briefly described. A more detailed account can be found in [31]and [32].

Set-up of experiments 1 and 2

In the first experiment the metaphorical extensions MORE IS UP, GOOD IS UP, and VIRTUE IS UP (see above) were investigated with 40 participants. Participants were required to enter data, acquired from an evaluation survey of 20 fictive hotels, into a simulated user interface. Participants were primed with sentences like "The staff is friendly." Then they were asked to respond to buttons located at UP and DOWN positions on the screen. The arrangement of buttons was either compatible or incompatible with one of the metaphors MORE, GOOD, and VIRTUE (Figure 2).

If conceptual image schema theory is right and these metaphors play a role in subconscious thinking, – also when users are presented with vertical button arrangements in user interfaces – then the users should be faster to respond to arrangements that are compatible with these metaphors than to arrangements that violate these metaphors. The experimental design was balanced in a way that comparison of both conditions yielded reaction time differences that reflected differences in mental effort rather than other efficiency indicators, such as time needed for pressing the button. As a measure of effectiveness error rates were measured. The hypothesis is that button arrangements incompatible with the metaphor should lead to more errors than button arrangements compatible with the metaphor. As a measure of satisfaction a questionnaire was administered, asking users to judge the suitability of button arrangements that were compatible and incompatible with the above metaphors. As a hypothesis, compatible button arrangements should be judged to be more suitable than incompatible button arrangements.

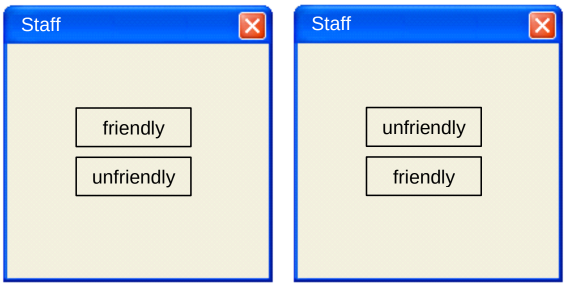

Figure 2. Experiment 1: Examples of vertical button arrangements for the metaphor VIRTUE IS UP, DEPRAVITY IS DOWN (left: compatible with the metaphor, right: incompatible).

In the second experiment an additional element was introduced: a slider representing the SCALE image schema. In contrast to the first experiment, the second focussed on two types of metaphorical extensions only: quantitative (MORE IS UP) and qualitative (GOOD IS UP). Another 40 participants took part. They were primed randomly with the words "more" or "less", "better" or "worse" and asked to move the slider into the appropriate direction. Again, the slider labels were either arranged to be compatible or incompatible to the respective metaphorical extension (Figure 3). The same measures as in the first experiment were taken (response times, error rates, and subjective judgments). Also, the same hypotheses apply.

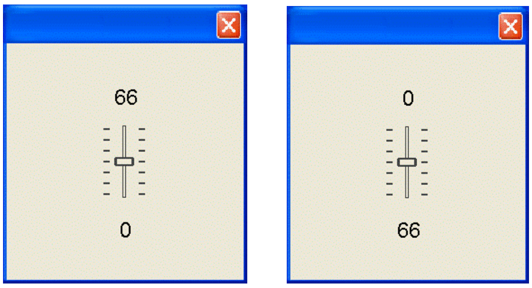

Figure 3. Experiment 2: Examples of vertical slider arrangements for the metaphor MORE IS UP, LESS IS DOWN (left: compatible with the metaphor, right: incompatible).

In each of the two experiments there were also conditions in which buttons (experiment 1) and sliders (experiment 2) were arranged horizontally. This was done to trigger a LEFT-RIGHT schema for comparison with the UP-DOWN conditions of the experiments. In contrast to the UP-DOWN schema, LEFT-RIGHT does sport only little metaphorical extensions in language (among them the *left* wing, *right* wing metaphor of political parties). No differences between LEFT-RIGHT and RIGHT-LEFT arrangements were expected with regard to VIRTUE and GOOD[2]. However, there seems to be a strong convention (or population stereotype) to put MORE to the RIGHT. This leads to the expectation of a (response time, error and subjective judgment) advantage of MORE metaphors when buttons or sliders are arranged in a way to put MORE to the RIGHT and LESS to the LEFT hand side. This is in correspondence with a digit ray found in various kinds of data charts.

Results

Table 3 contains the results of both experiments for response times and subjective judgments. Error rates could not be evaluated because almost no errors were made in this very simple task. Comparison of the compatible with the incompatible versions of the *vertical* button / slider arrangements shows that response times are faster with the compatible vertical arrangements in both experiments.

[2] Note that, although there is a positive slant to expressions like "This went *right*." or "He is my *right* hand.", there is no clear opposition between RIGHT and LEFT as there is between GOOD-IS-UP and BAD-IS-DOWN associations. They also seem to connote GOOD in a weaker and more indirect way than the labels used in the experiments, so they were not expected to produce measurable differences.

However, the data for the metaphor MORE IS UP in the first experiment fail to show statistical differences between the compatible and incompatible versions. Looking at the subjective judgments, a strong preference for vertical button layouts compatible with the metaphor is confirmed.
In the *horizontal* layouts there were generally no response time differences to be found between the compatibility versions, not even for the quantitative metaphor. In the horizontal layouts the preference data show a remarkable digit ray effect for the MORE metaphor. For GOOD the data is inconsistent between experiments. When using buttons as interface elements, users prefer GOOD to be located on the LEFT button and BAD at the RIGHT button. When introducing an additional SCALE schema by using a slider, the preferences are reversed. Now BAD is preferred on the LEFT and GOOD on the RIGHT.

Table 3. Results of the two validation experiments (see text). Confirmation of hypotheses is marked with ☑, rejection with ☒. Cells also contain a statement about the direction of the difference or equality, e.g. U<D.

Layout	**Vertical (UP-DOWN)**		**Horizontal (LEFT-RIGHT)**	
Dependant variables	**Response time (efficiency)**	**Subjective judgement (satisfaction)**	**Response time (efficiency)**	**Subjective judgement (satisfaction)**
Experiment 1: buttons (CONTAINER)	VIRTUE ☑ U<D GOOD ☑ U<D MORE ☒ U=D	VIRTUE ☑ U>D GOOD ☑ U>D MORE ☑ U>D	VIRTUE ☑ L=R GOOD ☑ L=R MORE ☒ L=R	VIRTUE ☑ L=R GOOD ☒ L>R MORE ☑ L<R
Experiment 2: sliders (SCALE)	GOOD☑ U<D MORE ☑ U<D	GOOD☑ U>D MORE ☑ U>D	GOOD ☑ L=R MORE ☒ L=R	GOOD ☒ L<R MORE ☑ L<R

Summary
Already with four image schemas - UP-DOWN, LEFT-RIGHT, CONTAINER and SCALE - there is a complex interplay of their metaphorical extensions. From the investigation of the UP-DOWN metaphors, it can be concluded, by and large, that designing in accordance to the metaphorical extensions of that image schema yields more intuitive interaction. The tendency of putting MORE to the RIGHT on a horizontal layout is confirmed by the subjective data, but missing from response time data. However, there are small variations to the theme: adding a SCALE schema seems to be important for emphasizing quantitative interpretations: only with sliders there is a difference between response time data in the vertical condition for the quantitative metaphor (MORE), and presence or absence of a SCALE is vital for the preferred poling in the weakly metaphorised LEFT-RIGHT condition for the qualitative metaphor (GOOD).
However, the validation of image schemata so far included a very selective set of schemas: UP-DOWN, LEFT-RIGHT, CONTAINER and SCALE. Further experimentation has to show, how other image schemas and their metaphorical extensions, e.g. from the group of FORCE schemas, might be applicable to intuitive user interface design. The result will not only be the validation of the theory to user interface design, but will also yield an empirically tested set of design rules.

5.2 Does applying the theory to user interface design support the design process?
Demonstrating the value of image schemas to the interface design process involves showing their applicability to the several phases of the user centred design process according to ISO 13407 [30] and their value for the design process itself (see above).

Image schematic analysis
The evaluation started with the analysis of given user interfaces in different fields of application. In these analyses the aim was to discover (1) how image schemas are represented by the various user interface elements and (2) how these image schemas are used to intuitively convey meaning and which abstract concepts are structured by them. For example, vertical sliders are instances of the UP-DOWN and SCALE image schemas that can be used for representing quantitative variables. Blinking warning lights are instances of the ATTRACTION image schema that is used to direct the user's attention towards important information.
These analyses yielded the following insights:
- Image schemas provide a powerful language for the analyses of user interfaces as different as

airplane cockpits (e.g. the A320), cash and ticket machines, or software platforms (e.g. Microsoft Windows' widgets).

- The effects image schemas have in user interfaces can be described as either (1) supporting usability, (2) hinder usability (e.g. a BLOCKAGE by an error message that contains no hint at RESTRAINT REMOVAL), (3) being neutral to usability or (4) that image schemas are missing (e.g. missing BLOCKAGE immediately after entering a false password). Image schematic analysis can point out weak spots in the design and make suggestions for improvement and help designers understand why user interfaces work or do not work as intended. Thus it can support the evaluation and improvement cycles in the design process.
- Image schematic analysis leads to the detection of implicit design rules not previously encountered in the user interface literature. So, many binary image schemas seem to have a default value, e.g. STRAIGHT is the default (its opposite being CURVED/NON-STRAIGHT). When this default value is used, it conveys "a normal state of affairs", while using the opposite conveys a special meaning. For example, a line on a user interface usually takes a STRAIGHT form and is seen to be neutral. A CURVED line is used to convey emotion or indicate specific circumstances. Image schematic analysis also shows which image schema representations can be substituted by others. For instance, a LINK image schema need not always be visually explicit, because a LINK effect can be achieved by placing interaction elements sufficiently NEAR each other: for instance, on a cash machine the indication of where to put in the bank card is given by an image of a bank card (MATCHING) that is NEAR the card slot. If this image is further away, an explicit LINK (e.g. a drawn line) needs to be placed between the bank card image and the card slot.
- Image schematic analysis shows that the perceived strength of an image schema varies according to the user interface element chosen to represent it. For example, a LINKAGE of moderate strength between two interface elements can be evoked by a line drawn between them. The LINKAGE is weakened when a dashed line is used. It is made stronger by using a line of glowing LEDs. It is even stronger when the LEDs are also blinking.
- Image schema analysis reveals the constraints of design environments. For example, it is easy to find direct applications of FORCE schemas in the hardware environment of an airplane cockpit, but they are harder to find in software interfaces. By this, image schema analyses also reveal important design gaps and innovation potential: thinking about how FORCE schemas might be applied in software may point to novel and innovative solutions in software design.

Design Catalogue

The results of these analyses of different hard- and software user interfaces were collected into a catalogue containing user interface elements, their image-schematic classifications and the effects achieved by incorporating specific image schemas. The catalogue is accessible via WWW [33] and will be open to the community for search and further input. By collecting the results of the user interface analyses in a catalogue, interface designers are provided with a tool for looking up examples of good and bad uses of image schemas; they get inspiration on how to represent them at the user interface and also what meaning their usage is conveying to the user. The catalogue is searchable for every field it contains. It also contains linguistic examples of metaphorical extensions of image schemas. By this it points to further application areas of image schemas going beyond what has been considered in user interface design so far.

Novel user interface concepts

Image schemas are not only useful for the analysis of existing user interfaces. They also can be used when designing novel technology to understand and manipulate the effects of specific user interface elements and parameters. Two studies with the focus on novel interfaces have been conducted. The first was about designing interfaces for tangible interaction [34] and went beyond current design approaches in that field. The second study looked at haptic interaction patterns of drivers with highly intelligent and quasi autonomous vehicles [35].

Summary

Although the test of image schemas in user interface design is not complete yet, some preliminary conclusions can already be drawn. Image schemas seem to be helpful in different phases of user interface design. As far as has been shown, they can be employed for the evaluation and improvement of user interfaces. The compiled catalogue can be a useful tool for producing design solutions. It has been shown that image schemas provide an abstract language which can be used to talk about user interfaces. Currently a study is set up to test this language within the early phases of interface design in which the context of use and the requirements are specified. If successful, this can lead to a language that is able to cover the whole user interface design process, bridging the design gap between requirements and design. The analyses also show that image schema language can be learned within a few days to be able to apply it to user interface analysis. The studies conducted so far also suggest it to be easy to use and also produce convincing results within seconds. However, how useful they are for the design of complex interfaces will be revealed by a subsequent study concerned with the redesign of a business software package containing many abstract terms and processes.

6 CONCLUSION

By addressing a very vague concept – intuitive interaction – used in talking about product use, this work tries to make the market demand for intuitive use manageable for designers by deriving instruments and guidelines. The paper provided a definition of the concept of intuitive use and developed a framework for researching the concept. Requirements have been set up for testing theories of adjacent disciplines that are investigating phenomena based on intuitive information processing. A promising candidate theory from cognitive linguistics was put to the test. Although the investigation is far from being completed, it can be concluded that image schema theory has very good prospects to provide a design language and guidelines for designing user interfaces that are intuitive to use.

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