Metaphors as Tools for Intuitive Interaction with Technology

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Abstract

Intuitive interaction with technology is based on the unconscious application of prior knowledge by the user. Using conceptual metaphor theory and a continuum model of prior knowledge a quantitative review of 77 research articles on user interface metaphors was conducted. Of the 105 metaphors extracted, only 26 were found to draw on sensorimotor knowledge proposed to be the preferred knowledge level for designing intuitive interaction. Using Johnson's (1987) theory on image schemas and their metaphorical extensions it is shown how user interface design might benefit from tapping sensorimotor knowledge. An experimental approach to test the validity of the image schema and conceptual metaphor theories in user interface design is presented with an investigation of the UP-DOWN image schema. When interacting with vertical button arrangements that are compatible with conceptual metaphor users are faster than with incompatible button arrangements. Compatible button arrangements are also judged to be more suitable than incompatible ones.

Die Grundlage intuitiver Benutzung besteht in der unbewussten Anwendung von Vorwissen durch den Benutzer. Anhand eines Vorwissensmodells und der konzeptuellen Metapherntheorie als Basis wurde eine quantitative Durchsicht von 77 Forschungsartikeln zu User Interface Metaphern durchgeführt. Von den extrahierten 105 Metaphern konnten nur 26 in die, für die Gestaltung intuitiver Benutzung favorisierten, Ebene des sensomotorischen Wissens klassifiziert werden. Mit Hilfe der Theorie der Image Schemata und ihren metaphorischen Erweiterungen von Johnson (1987) wird gezeigt, welche Vorteile der Einsatz sensomotorischen Wissens für die Gestaltung von Benutzungsschnittstellen birgt. Eine experimentalpsychologische Methode wird vorgestellt, mit dem die Gültigkeit der Image Schema Theorie für die Gestaltung von Benutzungsschnittstellen anhand des up-down Schemas überprüft wird. Bei der Interaktion mit vertikal angeordneten Tasten, deren Beschriftungen kompatibel mit konzeptuellen Metaphern sind, sind die Benutzer nicht nur schneller als mit inkompatiblen Beschriftungen - die kompatiblen Beschriftungen werden auch als besser geeignet für die Dateneingabe eingeschätzt.

1. Introduction

"Intuitive use" has become a buzzword when talking about interactive technology and is used by producers and customers alike. But there is no agreed consensus of what the term really means and how we can achieve building products that are intuitive to use. This paper will start with a brief overview of why design for intuitive use is necessary today and will give a definition of intuitive use. The main focus of the paper is set on metaphor as one of the major tools for designing intuitive interaction. Two empirical studies are presented.

One is a review of research articles on user interface metaphors, the other is an experimental validation of Johnson's (1987) theory on image schemas and their metaphorical extensions. Background to both studies is the conceptual metaphor theory first presented by Lakoff and Johnson (1980), which will be described in another section.

2. Design for intuitive use - why?

The demand for technology that is 'intuitive to use' has never been as high as it is today. The main factor causing this 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. Contributing to this is the increasing complexity of products because of enhanced functionality and personalisation issues. Think for instance of the multifunctionality of mobile phones that has been extended with cameras, media players, and organizers. Simultaneously 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, in the industrial sector we see a shift from hardware to software interfaces which goes along with a higher level of abstraction to the use of products.

As a consequence of these developments technology acceptance problems arise. The increasing *technological* convergence of products makes 'intuitive use' one of the unique selling propositions on competitive markets. It is no wonder that we are seeing products 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". Also, many IT research proposals use these magic words to ensure funding by research foundations.

3. Intuitive interaction – what is it?

Although 'intuitive interaction' seems to be the most widely used concept both in human-computer interaction research and product marketing brochures, formal definitions of the concepts are hard to find. Only two groups of researchers seem to have been tackling the problem recently: Thea Blackler and her colleagues in Australia (Blackler, Popovic & Mahar, 2005) and our IUUI

(Intuitive Use of User Interfaces) research group in Germany. Empirical work and theoretical considerations lead us to the following definition of 'intuitive use': *A technical system is intuitively usable if the users' unconscious application of prior knowledge leads to effective interaction* (Mohs, Hurtienne, Israel, Naumann, Kindsmüller, Meyer & Pohlmeyer, 2006:130).

Two concepts of this definition need further explanation. One is the notion of 'prior knowledge', the other is 'unconscious application'.

3.1 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 last three levels there might be specialist knowledge about using respective *tools* and technologies (see figure 1).

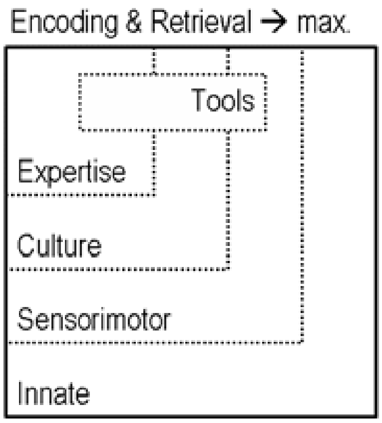

Figure 1: Continuum of knowledge in intuitive interaction

The first, and lowest, level of the continuum consists of *innate* knowledge - '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 unconscious 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 (Gibson, 1979) and the later discussed image schemata (Johnson, 1987) are residing at this level of knowledge. The next level is about knowledge specific to the *culture* an individual lives in. What is known within the western group of cultures is not necessarily equivalent to the knowledge of people in eastern cultures (e.g. the appropriate colour at funerals). The most specific level of knowledge is *expertise*, that is specialist knowledge acquired in ones profession, for example as a doctor, mechanic, or accounting clerk; and in hobbies (e.g. riding, surfing, online-gaming). Across the sensorimotor, culture and expertise levels of knowledge we also distinguish knowledge about *tools*. Tool knowledge seems to be an important reference when designing user interfaces. At the sensorimotor level there are primitive tools like sticks for extending one's reach and stones used as weights. At the culture level we find tools commonly used by people, like ball point pens for writing, pocket lamps for lighting, or cell phones for communication. At the last stage there is the knowledge acquired from using *tools* in one's area of expertise, for example image editing tools, enterprise resource planning (ERP) systems, or CNC machines. Even within the same domain of expertise (e.g. graphic design) there may be differing knowledge on the tool level of the continuum, depending on the kind of tools used (e.g. Corel Paint Shop vs. Adobe Photoshop).

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. Then, the further we rise 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 we may assign 'intuitive use' according to the above definition – as long as it is *unconsciously* applied by users.

3.2 Unconscious application of prior knowledge

The application of knowledge may be unconscious from the beginning on (as with reflexes) or may have become unconscious 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 unconsciously than knowledge from the upper levels. If the unconscious application of knowledge is a precondition for intuitive use, it will be more common 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 we move on the continuum the larger and more heterogeneous the user groups we can reach are. While almost everyone will have a concept of 'verticality' (sensorimotor level), not everyone understands the Corel Paint Shop 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 to the design of systems with a high demand on security (control of aircraft or of nuclear power plant).
- Unconscious 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 working task at hand instead of wasting time and mental effort on figuring out how a piece of technology works.

4. Metaphor as a Tool for Designing Intuitive Interaction

Many issues in contemporary research on metaphor are inspired by the view of Lakoff and Johnson expressed in the following statement (1980:5): "The essence of metaphor is understanding and experiencing one kind of thing in terms of another." Lakoff and Johnson see metaphor not as a mere figure of speech but as a fundamental cognitive mechanism, where experiential structure is projected from a source domain to a target domain. Mostly the source domain will be more familiar and concrete and the target domain more abstract or less familiar. As, with this approach, metaphor is not bound any more to linguistic expressions, they term their approach "conceptual metaphor theory". Concepts constitute knowledge, and it is often claimed that conceptual metaphors are working preconsciously or unconsciously: "The system of conventional conceptual metaphor is mostly unconscious, automatic, and is used with no noticeable effort, just like our linguistic system and the rest of our conceptual system." Lakoff (1993:245).

This definition of metaphor as being a tool for thinking rather than language and constituting knowledge that is applied unconsciously goes in line with our definition of intuitive interaction with technology. Therefore it might be interesting to look into the issue of conceptual metaphor a bit deeper and see whether we can use it in the domain of user interface design.

Indeed, the term "metaphor" has long been used in user interface design without any reference to conceptual metaphor theory. Metaphor has often been proposed to be one of the primary means for designing intuitive human-product interaction (e.g. Blackler, 2006). Large software producers like Microsoft or Apple recommend the use of user interface metaphors in their styleguides for programmers:

- "Familiar metaphors provide a direct and intuitive interface for user tasks. By allowing users to transfer their knowledge and experience, metaphors make it easier to predict and learn the behaviors of software-based representations." (Microsoft Corporation, 2004)
- "Take advantage of people's knowledge of the world by using metaphors to convey concepts and features of your application. Metaphors are the building blocks in the user's mental model of a task. Use metaphors that represent concrete, familiar ideas, and make the metaphors obvious, so that users can apply a set of expectations to the computer environment." (Apple Computer, Inc., 2006:39)

User interface metaphors can be one means for designing intuitive Human-Product Interfaces. Similar to Lakoff and Johnson (1980), the Handbook of Human-Computer Interaction says "metaphors allow the transference or *mapping* of knowledge from a *source domain* (familiar area of knowledge) to a *target domain* (unfamiliar area or situation), enabling humans to use specific prior knowledge and experience for understanding and behaving in situations that are novel or unfamiliar." (Neale and Carroll, 1997:441).

In user interfaces this mapping of knowledge is possible because the implementation model (the technology) and the represented model (the user interface) can be decoupled (figure 2). For example, the implementation model of a software application for travel management might be an Oracle database system. The designer now has to choose the model represented on the user interface. A model closely resembling the implementation model would be the mere presentation of database tables on the user interface. The designer would do a better job when he or she first analyzes the mental model users have of their travel management tasks, e.g. when planning an itinerary. Then the designer should make the represented model match the mental model as closely as possible. This for instance might result in a graphical interface presenting a map where users choose travel destinations by mouse clicks on a map and by selecting dates from a calendar-like representation.

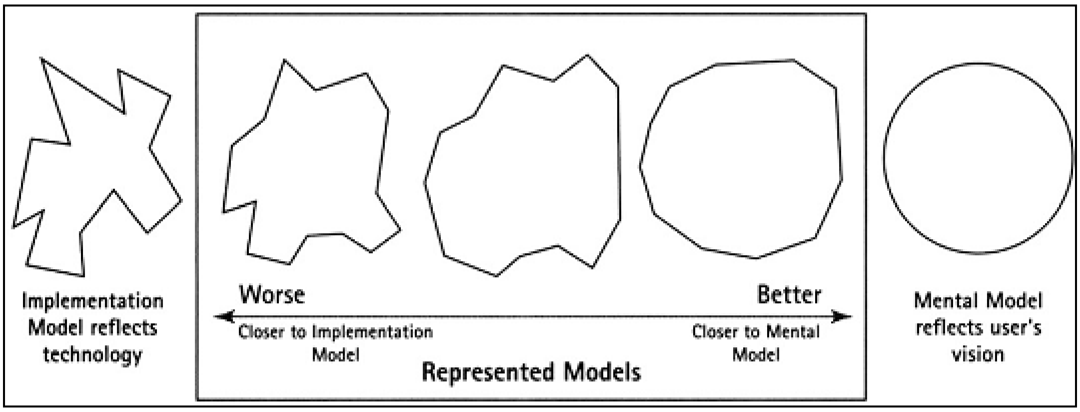

Figure 2: In software the implementation model can be decoupled from the represented model (figure taken from Cooper & Reimann, 2003:23)

Using metaphors for represented models is not just supporting the mental model of users - there are also benefits for the designers. Metaphors can help them to generate creative design decisions, maintain consistency in the interface, keep the number of design decisions manageable, and provide a rationale for the design decisions adopted.

The term 'metaphor' has been in use in the user interface design community since the early eighties, when the first Graphical User Interfaces (GUI) appeared. One famous example is the office metaphor first employed for the computer XeroxStar 8010, originally termed 'the user illusion'. Figure 3 shows an example screen depicting familiar objects like post-in and -out boxes, a trash can, folders, documents, and a calculator.

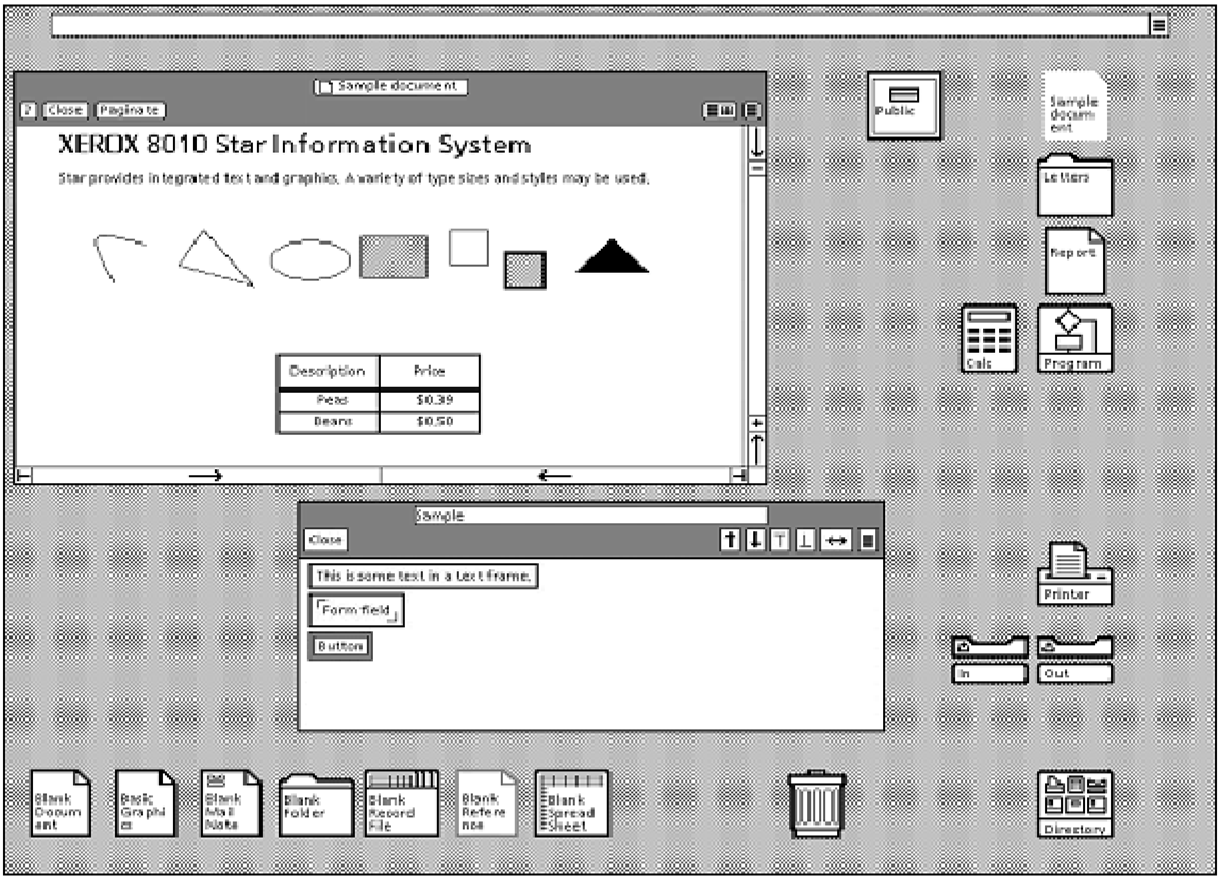

Figure 3: The first Graphical User Interface on the XeroxStar 8010 employs many metaphors

Trying to locate the office metaphor on our knowledge continuum we find that it is located on quite a high level of knowledge. Knowledge about offices and their equipment is not shared by all members of a culture, so we have to put it into the categories 'expertise' and 'tool (expertise)'. Although the office - or desktop - metaphor has been such a wide spread success, it also yielded much criticism (e.g. Ravasio et al, 2004). It has been remarked that it does not suit the task of information management and retrieval well, because it remains limited to the concepts of its source domain: the file cabinet (Mander, Salomon & Wong, 1992; Fertig, Freeman & Gelernter, 1996). Manipulation of new data types like music and pictures do not match the desktop metaphor well (Johnson, 2002). Also the office metaphor is not accessible to user groups unfamiliar with office environments (e.g. children, people in developing countries).

In the next section of this paper we will be looking into several published descriptions of applications of user interface metaphors and will determine which level of our knowledge continuum they refer to. According to the reasons given above, metaphors based on knowledge on lower levels of the continuum will be judged to be more intuitive to use than metaphors drawing on a higher level of knowledge. In the subsequent section a promising approach rooted in Lakoff and Johnson's conceptual metaphor theory and based on the sensorimotor level of the knowledge continuum will be discussed: image schemas and their metaphorical extensions. Some empirical work testing metaphorical extensions of a specific image schema will also be described.

5. Study 1: Conceptual Metaphor in User Interfaces

Applying metaphors in user interfaces does not per se guarantee intuitive interaction. Our definition requires that the use of prior knowledge must also be unconscious. We have already seen that the likelihood of intuitive interaction increases, the more basic the knowledge applied by the user is. This study was set up to investigate a wider range of papers describing applications of user interface metaphors in order to see what conceptual metaphors are used and to which level of the knowledge continuum their source domains are related.

5.1 Method

Seventy-seven papers were retrieved through the ACM and IEEE digital libraries and additional Google searches. In order to be collected each paper had to describe at least one application of user interface metaphors along with a design rationale. Then metaphors, their source and their target domains were extracted from each paper. The findings were assigned a level of the knowledge continuum, according to their source domain and their applied design rationale. The design rationale determined categorisation. For example, when the paper was describing a mirror as the source domain for the user interface metaphor rather than the more basic concept of reflection, the level of tool/culture was assigned instead of the sensorimotor level. As several user interface metaphors could be described within one paper and these metaphors could be assigned to different levels of knowledge, multiple classifications per paper were possible (totalling 105 classifications). A second classification has been done according to target domains to determine the most common target domains and their typical metaphorical mappings.

5.2 Results

Table 1 shows the results of assigning metaphors to the levels of the knowledge continuum. Almost two thirds of the user interface metaphors draw their source concepts from *cultural* knowledge – be it general cultural skills like navigating a city or using culture specific tools like cupboards and photo albums. A meagre 13% of the user interface metaphors are recruiting knowledge from the *expertise* and *tool/expertise* levels. Also within the expertise level the degree of specialisation of knowledge remains fairly low. Although knowledge about offices, libraries and video games might not be found in each member of our culture, it is rather common within a larger share of the population. Only a few user interface metaphors, like a lab bench in a software application for learning chemistry (Nishimura et al., 2004:247), refer to knowledge available only to small user groups. Source domains from the *sensorimotor* level have a share of 25%. Many instances of this level draw on spatial cognitive abilities, simple everyday physics or basic experiential metaphors like MORE IS UP, LESS IS DOWN. No user interface metaphors could be assigned to the *tool/sensorimotor* and the *innate* level of the knowledge continuum.

Knowledge level of source concept	**Frequency of occurrence**	**Example source concepts**	**Example target domains**
tool (expertise)	| | | | | | 6	professional graphics software	multi-item selection
		video games	virtual learning environment
		Joystick	selection and navigation in Virtual Reality
Expertise	| | | | | | | | 8	office information management	information retrieval; operating system
		Library	metadata visualisation of documents
tool (culture)	| | | | | | | | | | | | | | | | | | | | 20	ring binder with tabs	operating system
		photo album	multimedia file system
		cupboard, blackboard	visual query language
		Book	information retrieval and presentation
Culture	| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |	presentation of motion in comics	visualisation of dynamic data
		City	operating system
		Buildings	virtual navigation in 3D
tool (sensorimotor)	45 0	not available	not available
Sensorimotor	| | | | | | | | | | | | | | | | | | | | | | | | | | 26	perspective, zoom	Geographic information systems
		simple gestures (more is up, less is down)	user interface of a mobile music player
		movement in space	acoustic interface for blind users
Innate	0	not available	not available
Total	105		

Table 1: User interface metaphors categorised by the levels of the knowledge continuum

Results of the second classification (table 2) give an overview of the most common target domains of user interface metaphors in the analysed research papers. The most frequently occurring target domain is *file management* (30%). File management not only includes the storing, retrieving and processing of virtual documents like text files, photographs or presentation slides, it might also include personal information such as e-mails, addresses, appointments & deadlines, task lists, etc. Several papers are concerned with using organizational principles known from an office environment for managing digital files. A very common theme is organizing documents in form of *piles*. This knowledge is transferred from the familiar use of piles of paper documents to organize digital data in virtual piles that permit automatic sorting, reshuffling as well as searching and displaying the information contained within them (Mander, Salomon & Wong, 1992; Agarawala & Balakrshnan, 2006). Other metaphors for personal information management rely on users' domain knowledge about using books, libraries, museums, photo albums, magazines, diaries or maps.

Metaphors for *Auditory Interfaces* are mainly found on the sensorimotor level of knowledge. Auditory interfaces are often designed for providing an interface to users that are blind or visually impaired. Many of these metaphors use direct spatial translations of visual displays into auditory-spatial displays. Others map spatial variables onto acoustic variables like pitch or loudness. In the paper of Walker & Kramer (1996) variables commonly found in process control applications (temperature, pressure, size, and flow rate of fluids) have been mapped onto acoustic variables (pitch, loudness, onset, tempo) and their effectiveness has been investigated.

Target domain	Frequency of occurrence	Examples of metaphors
File Management	| | | | | | | | | | | | | | | | | | | | | | | 23	FILE MANAGEMENT IS MANAGING PILES OF DOCUMENTS FILE MANAGEMENT IS USING A LIBRARY FILE MANAGEMENT IS NAVIGATION IN ROOMS FILE MANAGEMENT IS USING AN OFFICE FILE MANAGEMENT IS USING A BOOK FILE MANAGEMENT IS USING A GEOGRAPHIC MAP FILE MANAGEMENT IS TIME TRAVELLING
Auditory interfaces	| | | | | | | | 8	ACOUSTIC EVENTS ARE VISUAL EVENTS IN SPACE ACOUSTIC DATA NAVIGATION IS SPATIAL DATA NAVIGATION PROCESS CONTROL VARIABLES ARE ACOUSTIC VARIABLES LISTENING TO MUSIC IS DRIVING A CAR PITCH IS DISTANCE
E-Learning	| | | | | | | 7	E-LEARNING IS WATCHING A THEATRE PLAY E-LEARNING IS PLAYING VIDEO GAMES E-LEARNING IS USING TOOLS FROM THE SUBJECT DOMAIN TO BE LEARNED E-LEARNING IS TRAVELLING
WWW / Internet	| | | | | | 6	WWW-BROWSING IS WATCHING TV WWW-BROWSING IS USING A SHOPPING MALL WWW-BROWSING IS TRAVELLING WWW-BROWSING IS USING A LIBRARY
3D & Virtual Reality Environments (3DVRE)	| | | | | | 6	NAVIGATING 3DVRE IS USING MAGIC DEVICES NAVIGATING 3DVRE IS NAVIGATING A CITY / A LANDSCAPE / A SOLAR SYSTEM NAVIGATING 3DVRE IS FLYING

Table 2: Frequent target domains and some of their metaphors

E-Learning applications have been using metaphors of travelling, video gaming or theatre plays. Also tools from the subject area that has to be learned are used. For example, a labbench is used for delivering virtual chemistry lessons (Nishimura et al., 2004:247) or an old-fashioned telescope facilitates e-learning about history, in this case Renaissance innovations (Angeli, Sutcliffe & Hartmann, 2006:271).

WWW-browsing metaphors refer to readily available knowledge of moving in space, travelling, and using a shopping mall. They also build on knowledge of using media, for example books in a library or the TV set.

Navigation in *three dimensional virtual environments* often is conceptualised as navigating a city, a landscape, as flying, or as navigating a solar system. Another approach is the application of magic devices like a flying carpet or voodoo dolls (Poupyrev, 2001).

5.3 Discussion

The analysis showed that metaphors are quite abundant in user interfaces and are deliberately used to transfer knowledge from familiar source domains to the new target domain of computer applications. Most user interface metaphors described can be classified at the culture level, many at the sensorimotor level of the knowledge continuum and a few at the expertise level. However, at the expertise level most metaphors refer to fairly wide spread knowledge about office equipment or library organization. Thus, most of the metaphors will be quite well understood by their target audience, at least within western culture.

However, the use of research articles to analyze metaphor intuitiveness alone does not prove that they are also effective in real contexts of use. Although all of the metaphors of the research papers have been implemented in software applications, we do not know whether they really enhance the effectiveness, efficiency, and satisfaction of users interacting with these systems. Also, metaphors published in papers might be the selected few which underwent extensive reasoning, seemed innovative enough to write about, or just offered themes that are currently en vogue in the research community (like virtual reality and auditory interfaces). Quite clearly, our analysis has to be supplemented by an empirical study of real interfaces. Maybe there are different metaphors out there, relying on knowledge which is more specialised than the metaphors in the research papers evaluated.

From our reasoning on intuitive interaction as well as the levels of the continuum of knowledge and the fact that metaphors are used as a means for designing intuitive interaction we expected to find the most metaphors at the lower levels of the continuum, because this was the most likely place to find unconscious application of prior knowledge. In graphical terms, we would expect a pyramid-shaped form of the metaphor frequencies across the levels. What we have got, however, is a convex form: only a few metaphors are at the expertise level, most are at the cultural level, and some metaphors are at the sensorimotor level. The lack of metaphors at the innate level might be explained with the difficulties of converting data on instincts and reflexes into utilisable rules for designing user interfaces. Compared to our expectations, metaphors at the sensorimotor level are referred to relatively little. The next section of the paper will try to change this by introducing the notions of image schemata and their metaphorical extensions and empirically investigating their validity for use in building user interfaces that are intuitively usable.

6. Intuitive interaction at the sensorimotor level: Image schemas and their metaphorical extensions

Image schemas and their metaphorical extensions are constituents of a recent theory on embodied mental representations put forward by Johnson (1987), which is fully compatible with conceptual metaphor theory (Lakoff & Johnson, 1980). This section will shortly describe the theory, discuss some applications of image schemas and their metaphorical extensions in user interfaces and then describe an empirical study representing an approach for validating image schemas and their metaphorical extensions for use in user interface design.

6.1 What are image schemas?

Image schemas are abstract representations of recurring dynamic patterns of bodily interactions that structure the way we understand the world (Johnson, 1987). The CONTAINER schema, for example, forms the basis of our daily experiences with houses, rooms, boxes, tea pots, cups, cars etc. A CONTAINER is characterized by an inside, an outside, and a boundary between them. Image schemas are much more abstract than images. So it is easy to form a mental image of an hour glass. However, image schemas are much more basic. For example, an image schematic analysis of the hour glass would not detect an 'hour glass schema' but the combination of two CONTAINER schemas connected via a LINK. Both CONTAINERS may be half FULL with a SUBSTANCE (image schemas are written in small caps).

Image schemas are schematic in nature and, as they capture the structural contours of sensory-motor experience, they are not just symbols. 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 (Hampe, 2005; Johnson, 1987). Table 3 organizes them into eight groups. Their universal character, their - in the course of life - extremely frequent encoding in and retrieval from memory and their unconscious processing makes them interesting for using them as patterns for designing user interfaces. A simple example for the UP-DOWN schema is that a slider is moved upwards and the digital representation, e.g. of a 3D structure in a CAD program, will follow.

Group	Image Schemas
BASIC SCHEMAS	SUBSTANCE, OBJECT
SPACE	UP-DOWN, LEFT-RIGHT, NEAR-FAR, FRONT-BACK, CENTER-PERIPHERY, STRAIGHT-CURVED, CONTACT, PATH, SCALE, LOCATION
CONTAIN-MENT	CONTAINER, IN-OUT, CONTENT, FULL-EMPTY, SURFACE
IDENTITY	FACE, MATCHING
MULTI-PLICITY	MERGING, COLLECTION, SPLITTING, PART-WHOLE, COUNT-MASS, LINKAGE
PROCESS	SUPERIMPOSITION, 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, SMOOTH-ROUGH

Table 3: List of image schemas, historically grown and grouped by similarity.

6.2 Metaphorical Extensions

Although image schemas describe human experiences with the physical world, their actual strength lies in their metaphorical extension for structuring abstract concepts (Johnson, 1987; Lakoff & Johnson, 1980). Linguistic analyses have shown that image schemas can serve as source domains of countless metaphors (e.g. Baldauf, 1997).

In the following sections we would like to show how image schemas are metaphorically used in language to conceptualize more abstract domains. 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 (Gibbs, Beitel, Harrington & Sanders, 1994; Gibbs & Colston, 1995; Tversky, 2000; Langston & Kuban, 2002; Boroditsky & Ramscar, 2002; Meier & Robinson, 2004; Casasanto, Lozano & Garlock, 2005). 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 interaction. In the following sections we try to outline the application of image schemas for the analysis and the design of tangible interfaces.

7. Image Schemas and their metaphorical extensions in User Interfaces

In the following sections we will discuss examples of selected image schemas, review the linguistic evidence for their metaphorical extensions to abstract domains, and show how they might be used in the design of user interfaces. Because of the scarcely available space we will only give examples from two groups of image schemas, SPACE and CONTAINMENT.

7.1 SPACE schemas

SPACE schemas are especially interesting, since interaction with technology usually takes place in 2D (on screen) or 3D (in the environment) space. Also, since SPACE schemas reflect the vast experience people have with navigating space, their metaphoric extensions are especially rich. Only three of the space schemas will be introduced in detail to point out the opportunities for user interface design.

7.1.1 UP-DOWN

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 (i.e. placing interface elements above or below another) or in a dynamic fashion (moving objects vertically 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*. My income 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*. He does *high-quality* work. 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 Lakoff & Johnson, 1980:14-21 for more examples).

These metaphorical extensions can be transferred to user interfaces: moving a virtual slider upwards might be used to intensify the loudness of speakers when controlling an mp3-player (using the metaphor MORE IS UP) or indicate happiness within a networked social communication platform (using HAPPY IS UP). One also might think of displaying evaluation results of different hotels in a city (using GOOD IS UP).

7.1.2 PATH

A second important space schema is PATH. A PATH involves physical or metaphorical movement from place to place and consists of a starting point, a terminal point, and a series of contiguous locations (Johnson, 1987:113). Since the PATH schema is so ubiquitous in experience there is a rich collection of metaphorical extensions:

- PURPOSES ARE DESTINATIONS: He's *headed* for great things. I've got quite *a way to go* before I get my Ph.D.
- ACTORS ARE TRAVELERS: As *we* travel down life's path…
- STATES ARE LOCATIONS: He saw teaching as just a *stopover* on his way to bigger things.
- THE MEANS FOR ACHIEVING PURPOSES ARE ROUTES: If this doesn't work, I'll just try a different *route*.
- DIFFICULTIES ARE IMPEDIMENTS TO TRAVEL: He's *lost* his way. He has a *rocky road* ahead of him.
- PROGRESS IS DISTANCE TRAVELLED: We've come a *long way*.
- MAJOR CHOICES ARE CROSSROADS: She's at a *crossroads* in her life.

All of these metaphorical extensions may be employed, for instance, to design a project planning and tracking application. Sub-projects may be different routes, time is mapped to linear space, tokens represent project teams, milestones can be placed, certain routes can be opened or blocked, etc.

7.1.3 CENTER-PERIPHERY

The CENTER-PERIPHERY schema has much to do with the space that is within our reach. Our body is at the CENTER and things located at the PERIPHERY are not readily graspable. The most important metaphoric extension of this schema is

- IMPORTANCE IS CENTRALITY: Put *away* that thought. What is *central* here? That's just a *peripheral* issue.

The CENTER-PERIPHERY schema is used in user interfaces by presenting important functionalities in the CENTER of reach or the CENTER of attention and auxiliary functions into the PERIPHERY. Newer developments like hyperbolic trees put main search results into the CENTER of a hyperbolic tree and less important search results at the PERIPHERY (figure 4).

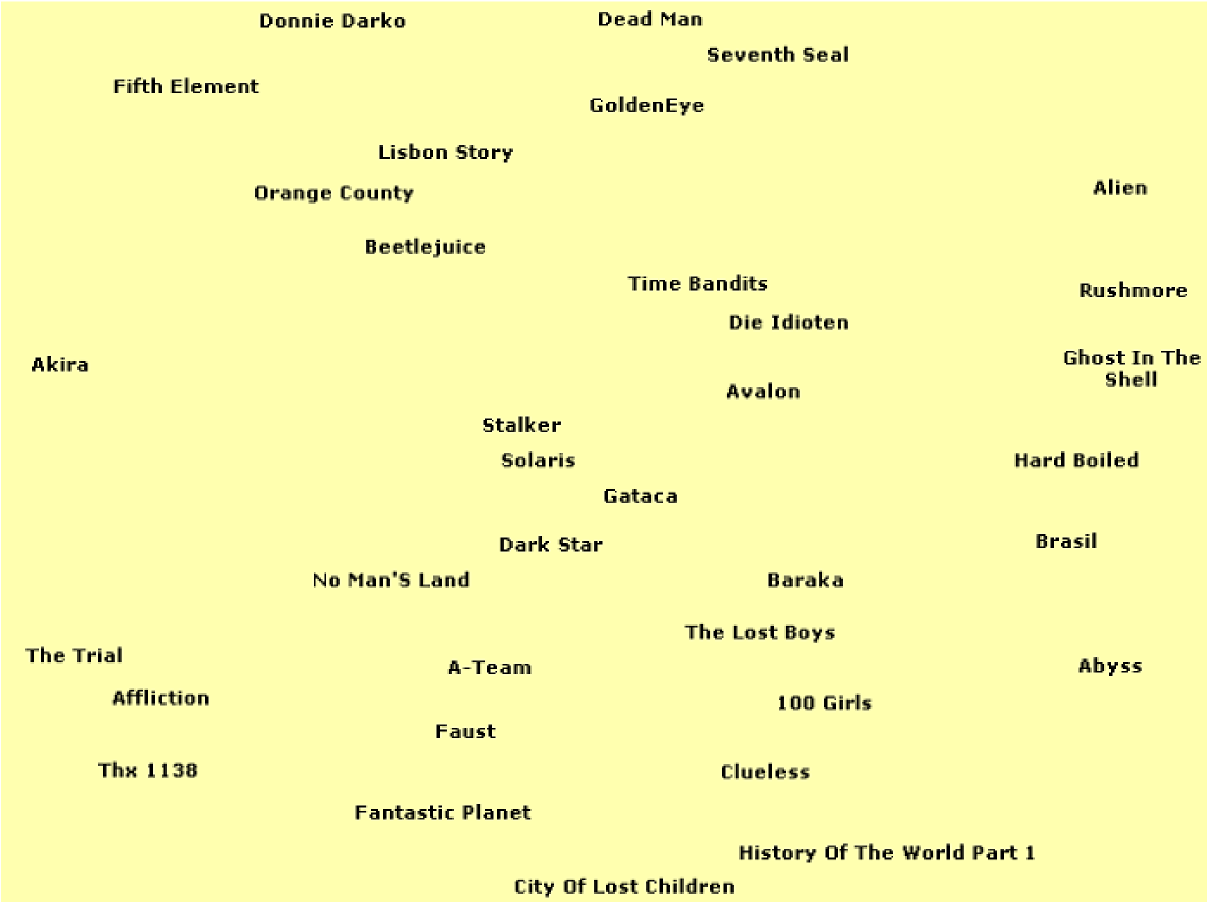

Figure 4: User interface from a movie recommendation application (www.gnovies.com).

Search results are arranged according to the metaphor IMPORTANCE IS CENTRALITY. Entering "solaris" will display the movie *Solaris* at the CENTER of the results page. Similar movies are displayed near the search result and less similar movies (that are less important to the music preferences of the user) are displayed at the PERIPHERY.

7.2 CONTAINMENT schemas

This group of image schemas includes the aforementioned CONTAINER, which is characterized by a physical or metaphorical boundary, an enclosed area or volume, and / or an excluded area or volume. Subjectively, i.e. experientially, a CONTAINER also involves differentiation and separation; protection from and resistance to external forces; enclosure and thus restriction and limitation of forces within the container. The consequences of this are a certain fixity of location, accessibility or inaccessibility of the content to view, and transitivity (i.e. when nesting containers within others). Part of a CONTAINER is a SURFACE, giving support to the CONTENT. Associated actions are IN and OUT movements that result in the CONTAINER being FULL or EMPTY.

CONTAINERS are quite abundant in user interfaces: there are file folders as CONTAINERS for documents, group boxes contain interface elements and input fields contain data (figure 5).

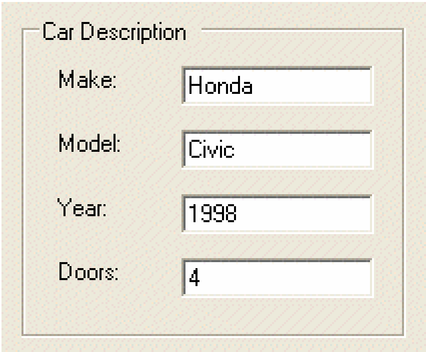

Figure 5: CONTAINERS in user interfaces: a group box containing input fields containing data

The metaphorical extensions of the CONTAINER schema are so large that only a few examples are given here:

- ACTIVITIES ARE CONTAINERS: *In* washing the windows I splashed water all over the floor. How did Jerry get *out* of painting the fences?
- STATES ARE CONTAINERS: Whenever I'm *in* trouble, she always bails me *out*. He's *in* love. She *entered* a state of euphoria.
- GROUPS OF INDIVIDUALS ARE CONTAINERS: He is an *out*sider. The proportion of females *in* the population has increased. It was bound to raise a serious debate *in* the party.
- LAND AREAS ARE CONTAINERS: There is a lot of land *in* Kansas. A clearing *in* the woods. What should I take with me for a walk *in* the South Downs?
- TIME IS A CONTAINER: *in* the 20th century, He did it *in* three minutes. *In* 1968. . . He's like something *out of* the last century.

As CONTAINERS are ubiquitous in computing, this list just gives some impression how CONTAINERS may be used to represent abstract data. For example, CONTAINERS in a user interface may represent different regions for simulating migration between countries or departments of a company. CONTAINERS may also be used to represent time periods for shift planning where the assignment of shifts is done by putting employee tokens into different containers representing early, late, and night shifts. Media may be sorted into CONTAINERS according to place (photos from the trip to Berlin, New York, Prague), group of individuals (photos of relatives, friends, colleagues), time period (movies of the thirties, forties and fifties), emotional state (joyful music, music for sad moments), etc.

8. Study 2: Metaphorical extensions of the UP-DOWN schema

As we have seen above, one of the most productive SPACE schemas in terms of its metaphorical extensions into other domains is UP-DOWN. While the ubiquity of these schemas has been proven for expressions in language, we also have to validate the claim of them being *conceptual* metaphors instead of only being a *language* phenomenon. Some experimental work has been done by Langston and colleagues to show that UP-DOWN metaphors really are a matter of thinking rather than just a matter of language. Their research has shown that violating UP-DOWN metaphors has effects on text comprehension (Langston & Terzo, 1998) and in some contexts UP-DOWN metaphors are used by readers when taking notes (Langston, Kuban & Logan, 2002).

But are UP-DOWN metaphors also useful tools for user interface design? Are conceptual UP-DOWN metaphors utilized by users interacting with user interface elements? The second study tries to find answers to this. In this study participants are required to enter data, acquired from an evaluation survey of hotels, into a simulated user interface. Participants were primed with a sentence like "The staff is friendly." Then they are asked to respond to buttons located at UP and DOWN positions on the screen. Four metaphors are investigated: (1) MORE IS UP, LESS IS DOWN (2) GOOD IS UP, BAD IS DOWN (3) VIRTUE IS UP, DEPRAVITY IS DOWN (4) HIGH STATUS IS UP, LOW STATUS IS DOWN. The arrangement of buttons can be either compatible or incompatible with one of the four metaphors (figure 6). If conceptual metaphor theory is right and these metaphors play a role in unconscious thinking – also when presented with vertical button arrangements in user interfaces - then users should be faster to respond to arrangements that are compatible with these metaphors than to arrangements that violate these metaphors. Users should also judge button arrangements that are compatible with these metaphors as more suitable for data entry than arrangements that are incompatible with the metaphors.

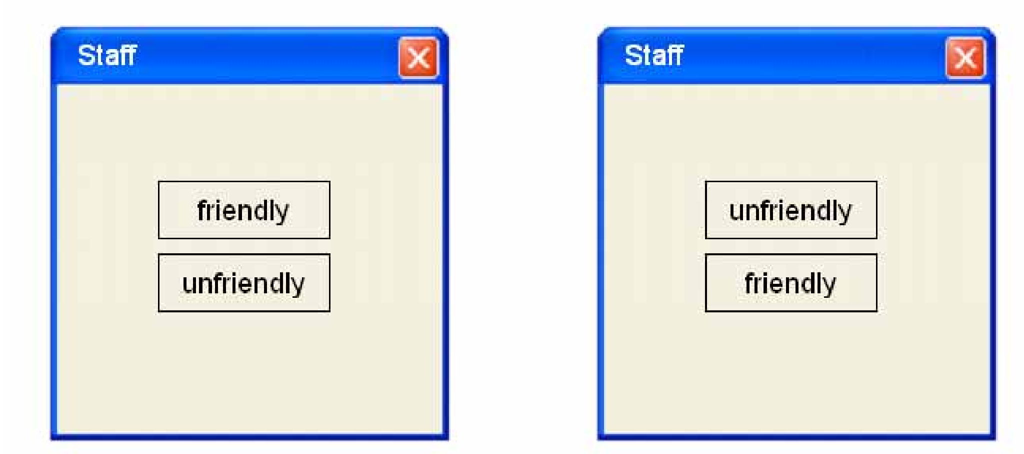

Figure 6: Examples of vertical button arrangements for the metaphor VIRTUE IS UP, DEPRAVITY IS DOWN (left: compatible with the metaphor, right: incompatible).

8.1 Method

8.1.1 Subjects

Participants were 40 native German speakers (17 male, 23 female) recruited from the campus of Technische Universität Berlin and beyond. Participation took place in exchange for payment.

8.1.2 Procedure

Participants were instructed to enter data into a software program for the evaluation of 20 hotels. Each hotel was evaluated concerning ten different aspects, which were in fact metaphorical extensions of the UP-DOWN schema. For each hotel the procedure was like this: On a screen the priming statement (e.g. "The staff is friendly.") was presented for 2000 milliseconds. Then the priming statement was replaced by a dialog box (see fig. 6) with a vertical arrangement of buttons. Participants responded with the upper or lower key on the keyboard, mirroring the arrangement of buttons on the screen. After their response had been collected, the next priming statement appeared, etc. The ten statements of each hotel were presented in a random order. To control for disturbing variables the same procedure was done with a horizontal arrangement of buttons. The sequence of the vertical and horizontal experimental conditions was randomly assigned to participants.

After the experiment participants were asked to fill in a questionnaire containing questions on the personally felt importance of the hotel characteristics, on demographic variables, and on judging the suitability of compatible and incompatible (as well as vertical and horizontal) button arrangements for entering hotel data.

8.1.3 Experimental design and stimuli

A within subjects design was used with two independent variables: metaphor (abbreviated subsequently as VIRTUE, GOOD, MORE, and STATUS, plus a non-metaphorical control, UP) and compatibility of button layout (compatible versus incompatible with the respective metaphor). Each metaphor was represented by two types of evaluative statements about a given hotel (e.g. VIRTUE by "The staff is friendly." and "The staff is competent."). Each sentence was also formulated in its opposite meaning (e.g. "The staff is unfriendly."). See table 4 for a collection of the stimuli used. The specifics of each statement (whether it was positively or negatively phrased) and the corresponding button labelling (whether it was compatible or incompatible with the metaphor) were randomly assigned to the hotels.

As dependant variables, response time (from the computer experiment) and suitability judgments for button arrangements (questionnaire) were measured.

Metaphor type	**Priming statements**	**Button labels**
VIRTUE	The staff is friendly (unfriendly). The staff is competent (incompetent).	friendly, unfriendly competent, incompetent
GOOD	The breakfast buffet is good (bad). The rail connections are good (bad).	good, bad good, bad
MORE	The hotel is booked by 90% (70%). The parking garage has 100 (30) lots.	90%, 70% 100, 30
STATUS	The hotel is in the city centre (suburbs). The hotel is a luxury (standard) hotel.	city centre, suburbs luxury, standard
Control: UP	The hotel bar is up (down). The meeting rooms are up (down).	up, down up, down

Table 4: Metaphor types and stimuli used in Study 2 (translated from German).

8.2 Results

8.2.1 Response times

Results of a two-way GLM repeated measures procedure with metaphor type and metaphor compatibility as within-subject factors show significant main effects for metaphor type, F(4, 156)=82.42, p<.001, and for metaphor compatibility F(1, 39)=33.16, p<.001. Also, the interaction effect of metaphor type with metaphor compatibility was significant, F(4, 156)=9.50, p<.001. Single comparisons using one-tailed paired t-tests with Bonferroni-Holm correction for multiple comparisons (family wise α=.05) show significant differences between button labelling compatible with the metaphor and button labelling incompatible with the metaphor for VIRTUE, t(39)=4.16, d=.40; GOOD, t(39)=2.58, d=.29; and the non-metaphorical control condition UP, t(39)=5.61, d=.62. There were no significant differences in response times for the metaphor types MORE, t(39)=0.42; and STATUS, t(39)=0.11. Results and comparisons are shown in figure 7.

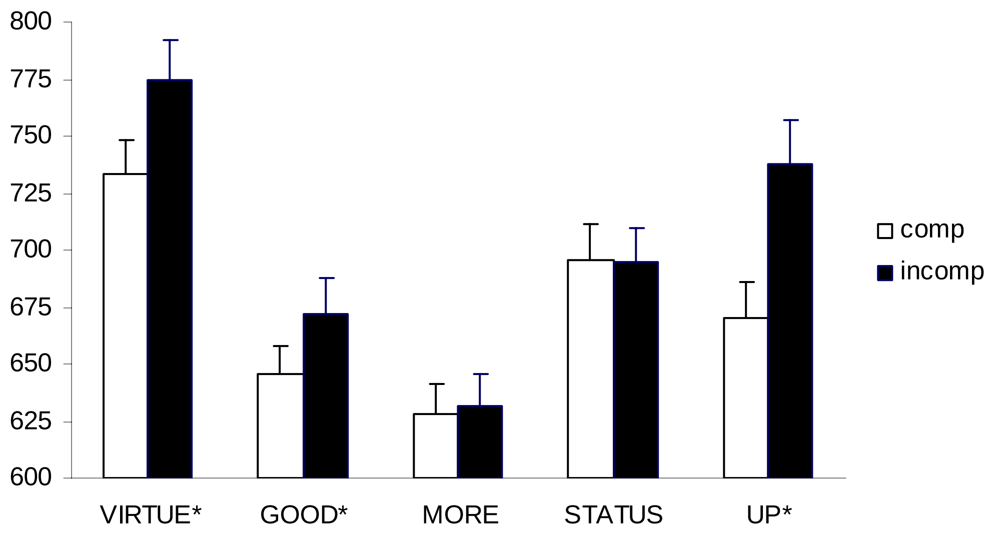

Figure 7: Response times in ms for vertical button arrangements that are compatible (comp) or incompatible (incomp) with specific metaphorical extensions of the UP-DOWN schema. Asterisks indicate statistical significance of differences between comp and incomp conditions (see text).

8.2.2 Suitability judgments.

Results of a two-way GLM repeated measures procedure with metaphor type and metaphor compatibility as within-subject factors show significant main effects for metaphor type, F(4, 156)=4.21, p<.01, and for metaphor compatibility F(1, 39)=181.51, p<.001. The interaction effect of metaphor type with metaphor compatibility was significant, too, F(4, 156)=38.35, p<.001. Single comparisons using one-tailed paired t-tests with Bonferroni-Holm correction for multiple comparisons (family wise α=.05) show significant differences between button labelling compatible with the metaphor and button labelling incompatible with the metaphor for all metaphor types: VIRTUE, t(39)=10.84, d=2.45; GOOD t(39)=14.71, d=3.17; MORE, t(39)=1.86, d=.51; STATUS, t(39)=3.4, d=.68; and the non-metaphorical control condition UP, t(39)=17.05, d=4.07. Results and comparisons are shown in figure 8.

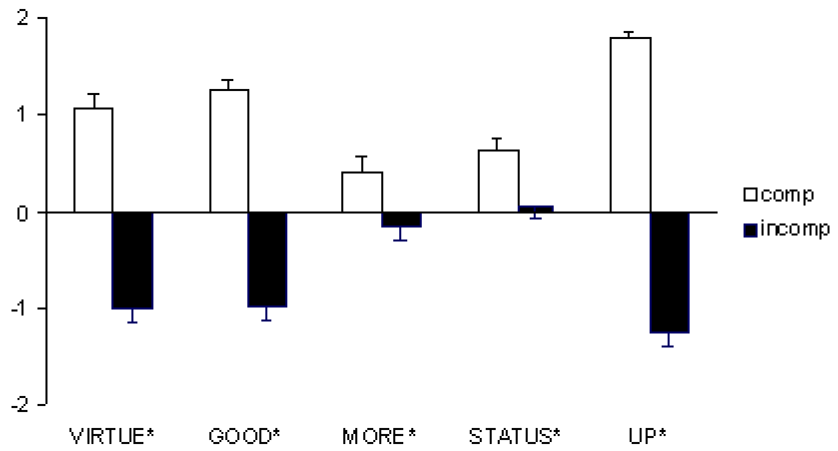

Figure 8: Suitability judgments for vertical button arrangements that are compatible (comp) or incompatible (incomp) with specific metaphorical extensions of the UP-DOWN schema. Positive numbers on the y-axis indicate agreement with, negative numbers indicate rejection of a particular type of button labelling. Asterisks indicate statistical significance of differences between comp and incomp conditions (see text).

Results for the horizontal button arrangement (the control condition) will not be presented here in detail. To sum up the results, there were no significant differences in response times for all four metaphor types VIRTUE, GOOD, MORE, and STATUS but mixed results for the suitability judgments. With these response time results alternative explanations regarding the differences between compatible and incompatible button arrangements in vertical condition could be ruled out.

8.3 Discussion

Results show that metaphorical extensions of the UP-DOWN image schema cannot only be found in language. They also make a difference when interacting with computers. Users interacting with vertical button layouts respond faster when the labelling is compatible with the metaphors GOOD IS UP, BAD IS DOWN or VIRTUE IS UP, DEPRAVITY IS DOWN than when it is not compatible. When asked for their subjective judgments, participants consider button layouts which are compatible with all four metaphors to be more suitable for data entry than button layouts which are incompatible with the metaphors. In this respect they behave similarly as if there was no metaphorical extension of the UP-DOWN schema present, as the comparison with a literal UP-DOWN labeling of the buttons shows. Effect sizes (labelled *d*) vary from very strong to medium for suitability judgments and from medium to small for reaction times.

While the data on suitability judgments confirm our hypothesis for each metaphor type, differences between the compatibility conditions for response time data can only be detected for two metaphor types: VIRTUE and GOOD. Why is there no effect for MORE and STATUS? We can only hint at the answers. MORE is the only metaphorical extension that is concerned with quantity, the other three (VIRTUE, GOOD, and STATUS) are about quality. Answers from the questionnaire show that the hotel characteristics of the MORE metaphor (number of parking lots and percentage of bookings) were not judged as very important by the participants. This does point to a failure to evoke a judgment of quality with these items. Users also seem to have neglected the quantity aspects of these items due to the overall setting of hotel *evaluation* and the presentation of numbers on two separated buttons. The latter points to the question: would it be different had the UP-DOWN schema not been represented by buttons but by a visual analog scale or a slider emphasizing aspects of the SCALE schema (and thus the quantitative aspects)? A more carefully controlled replication of the experiment must reveal whether these explanations are justified.

The results of the STATUS metaphor can be explained along similar lines. As our subjects were mainly students from Technische Universität Berlin, whether they dealt with a HIGH STATUS or a LOW STATUS hotel did not make a big difference to them. Their pragmatic decision would not be with the HIGH STATUS hotel because students are not known for ample supplies of money.

Here also a more carefully controlled replication of the experiment has to be carried out.

8.4 Conclusion

This study has shown that there is something in image schemas and their metaphorical extensions that is useful to user interface design. The effects of a user interface design element that is compatible with a single metaphor do not appear large at first sight (our study revealed about 5% gain in response time). But so far we only have looked at a single interface element – in sum, and across the whole user interface, the savings might well add up to more impressive figures. What is more, users strongly prefer interface solutions that are laid out in compatibility to conceptual metaphors. Thus metaphorical designs will greatly influence the satisfaction of users.

With the given experimental approach we have shown how the use of image schemas and their metaphorical extensions in user interface design might be investigated. The approach of this study might be generalized to the investigation of other image schemas and their metaphorical extensions: after selecting a suitable candidate schema, search for linguistic analyses providing metaphorical extensions, then translate their meaning into user interface elements and contexts of use, then build simple evaluation experiments in which metaphor violations are compared to metaphor conformity and differences are measured in terms of response times, error rates and subjective judgments by users.

Apart from the replication of our findings regarding the UP-DOWN schema we will extend our experimental research to test the utility of other image schemas and their metaphorical extensions. Promising candidates are SPACE schemas like CENTER-PERIPHERY, PATH, and SCALE as well as the FORCE schemas that will be especially interesting with haptic interaction.

9. Summary and Outlook

In this article, a definition of intuitive interaction has been introduced and the (user interface) metaphor has been identified as a major means for designing intuitive interaction. A continuum of knowledge has been presented with which it is possible to classify current applications of user interface metaphors.

The hypothesis is that the more basic the level of knowledge in the continuum a metaphor refers to is, the more likely it is that this knowledge is unconsciously applied and results in intuitive interaction. A survey of 77 research papers revealed that the knowledge level of the described metaphors often is fairly basic in the sense that many people (at least in western culture) will share the knowledge the metaphors use as their source domains. However, there seems to be more capacity to further exploit the more basic levels of the knowledge continuum. With Johnson's (1987) theory on image schemas and their metaphorical extensions an approach was presented that seems at the same time to be productive and innovative for the design of intuitive interaction. A first experiment was reported that was aimed at investigating the application of image schemas to user interface design and that provided encouraging results triggering further explorations. However, work does not stop here – there are about 40 image schemas that have to be tested for their usefulness for the design of intuitive interaction. Outcomes of these activities will not only be empirically evaluated guidelines for designers but also a theoretical foundation able to address many issues that user interface designers today have to decide on intuitively.

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