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Metaphors of Human Thinking in HCI: Habit, Stream of Thought, Awareness, Utterance, and Knowing

Erik Frøkjær & Kasper Hornbæk[1]
Department of Computing,University of Copenhagen, Copenhagen, Denmark
erikf@diku.dk, kash@diku.dk

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Abstract

Understanding human thinking is crucial in the design and evaluation of human-computer interaction. Inspired by introspective psychology, we present five metaphors of human thinking. The aim of the metaphors is to help designers to consider important traits of human thinking when designing. The metaphors capture aspects of human thinking virtually absent in recent years of HCI literature. As an example of the utility of the metaphors, we show how a selection of good and poor user interfaces can be appreciated in terms of the metaphors. The metaphors are also used to reinterpret central notions in human-computer interaction, such as consistency and information scent, in terms of human thinking. Further, we suggest the metaphors be used for evaluating interfaces.

1. Introduction

We present five metaphors related to the human thinking activity, and show by examples how the metaphors may serve to clarify aspects of designs of human-computer interaction (HCI).

For some years our research and teaching in human-computer interaction have been inspired by William James's and Peter Naur's descriptions of human thinking (James 1890; Naur 1988; Naur 1995; Naur 2000; Naur 2001). Similar descriptions along with many brilliant design discussions have lately been introduced to HCI in Jef Raskin's book 'The Humane Interface' (Raskin 2000). Naur's and Raskin's work are complementary to most psychology used in HCI, but is supported by extensive evidence from classic introspective psychology (James 1890), and from experimental psychology and neurology (Baars 1988; Baars 1997). Several of the aspects of human thinking described in this work are of critical importance to human-computer interaction: (1) the role of habit in most of our thought activity and behaviour—physical habits, automaticity, all linguistic activity, habits of reasoning; (2) the human experience of a stream of thought—the continuity of our thinking, the richness and wholeness of a person's mental objects, the dynamics of thought; (3) our awareness—shaped through a focus of attention, the fringes of mental objects, association, and reasoning; (4) the incompleteness of utterances in relation to the thinking underlying them and the ephemeral nature of those utterances; and (5) knowing—human knowing is always under construction and incomplete.

In this paper we present five metaphors of human thinking that cover the phenomena mentioned above. The contribution of the metaphors is threefold. First, the metaphors introduce a clear and recognizable way of talking about human thinking which we find absent in recent literature on HCI. Second, we use the metaphors to analyse commonly available user interfaces. This shows the utility of the metaphors in recognizing and exploiting important characteristics of human thinking. In addition we show how central notions in HCI can be understood in terms of the metaphors, which we claim lead to a gain in clarity and immediate understandability of these notions. Third, we suggest further application of the metaphors to user interface design and evaluation.

[1] The authors contributed equally to the paper.

In the next section, we present the metaphors and show how they describe aspects of human thinking crucial to HCI. Then we show how the metaphors can be used to describe important phenomena in HCI. Finally, we discuss limitations in our presentation and suggest further uses of the metaphors.

2. The Metaphors of Human Thinking

We describe thinking through five of its aspects which combined and separately catch important general properties that seem to be shared by human beings. Each aspect is described also by a metaphor meant to support the reader in keeping a clearer understanding useful in further studies and discussions. The number of metaphors is not important; nor is our choice of metaphors meant to catch all aspects of human thinking. Still we hope to show that the metaphors offer valuable and convenient descriptions of human thinking in HCI.

The five aspects of human thinking emphasized are habit, stream of thought, awareness, utterances, and knowing. We have chosen to present these aspects of human thinking by quotations from James (1890) and Naur (2000; 2001; 2002). Naur has carefully studied the 1377 pages of James's book The Principles of Psychology and through quotations, summaries and extended discussions illuminated James's work and to us made it more accessible. For readers who might not be aware of the continued importance of James's classical work in psychology, and who therefore might feel uncomfortable with our paper's building so directly on sources published more than hundred years ago, we quote the renowned cognitive psychologist Bernard Baars who in 1997 writes:

> 'Remarkably, the best source on the psychology of consciousness is still William James's elegant 'Principles of Psychology', first published in 1890. [...] James's thought must be understood in historical context, but the phenomena he describes so well have not changed one bit.', (Baars 1997, p. 35).

For the purpose of improving our understanding of human thinking, we have not found any sources in psychology better suited than The Principles of Psychology.

2.1. The Eroded Landscape Metaphor of Habits

Every person is like a landscape eroded by water. By this metaphor we mean to indicate how a person's formation of habits leads to more efficient actions and less conscious effort, like a landscape through erosion adapts for a more efficient and smooth flow of water. Creeks and rivers will, depending on changes in water flow, find new ways or become arid and sand up, in the same way as a person's habits will adjust to new circumstances and, if unpracticed, vanish.

According to James the most important general property of the thinking and behavior of people is that each person is a bundle of habits. Building on James, Naur writes (Naur 2002):

> 'All our grasping of things around us that we see, hear, feel, that which we call perception, is entirely a question of the habits each of us has trained. In addition our locomotion, the way we move our arms and legs while moving around, is almost entirely habitual. In addition, our talking with each other, the way we grasp what others say to us and the way we move our tongue, lips, and other organs of speech while talking, all this has been trained as habits. All education is a matter of training habits.
>
> Any part of a human organism may be involved in a habit. In a certain sense every habit involves the entire person.'

Further, James discusses the possible physiological basis of habits which also sheds light on the nature of habits (James 1890, vol. I, p. 105):

> 'Plasticity, then, in the wide sense of the word, means the possession of a structure weak enough to yield to an influence, but strong enough not to yield all at once. Each relatively stable phase of equilibrium in such a structure is marked by what we call a new set of habits. Organic matter, especially nervous tissue, seems endowed with a very extraordinary degree of plasticity of this sort; so that we may without hesitation lay down as our first proposition the following, that the phenomena of habit in living beings are due to the plasticity* of the organic materials of which their bodies are composed. *Note: In the sense above explained, which applies to inner structure as well as to outer form.'

2.2. Human Thinking as a Stream of Thought

The metaphor of human thinking as a stream of thought is the result of James's own choice. He says:

> 'Consciousness, then, does not appear to itself chopped up in bits. Such words as 'chain' or 'train' do not describe it fitly as it presents itself in the first instance. It is nothing jointed; it flows. A 'river' or a 'stream' are the metaphors by which it is most naturally described. In talking of it hereafter, let us call it the stream of thought, of consciousness, or of subjective life.' (James 1890, vol. I, p. 239).

Naur summarizes James's description of human thinking as stream of thought in this way:

> 'In William James's Principles of Psychology the stream of thought denotes something happening in all of our wake moments, to wit our experience of thinking and feeling. The stream of thought is known to every one of us through introspection, that is through our turning the attention inward, towards the way we experience our thoughts and feelings. What we may register through introspection is merely a picture of rough outlines. The stream of thought changes incessantly and has a vast number of details, most of which are present only vaguely, far more than may be seized by introspection.
>
> The stream of thought happens independently of our desire. We may, when we so wish, more or less successfully think of something definite, but we cannot make the stream of thought cease, as experienced by every person suffering from insomnia.
>
> The stream of thought may be described as something that flows, an incessantly changing, complicated mixture of something that may be denoted explicitly as images, sounds and bodily impressions, with additional vague moods and feelings. As stressed by James we do not in the stream of thought experience sharply delimited parts or elements of any kind. At each moment our thought is occupied by something that is complicated, but that is experienced as a whole. These wholes James calls thought objects [Our remark: also called 'mental objects']. Within each thought object one may distinguish between something more at the center, that which is the subject of our attention, and something that forms a fringe. […] [E]very thought object embraces feelings, including those of the personal well-being, moods and bodily presence.' (Naur 2001, p. 85).

Properties in a person's stream of thought can be distinguished and retained with a sense of sameness, which according to James (1890) function as 'the keel and backbone of human thinking' (vol. I, p. 459).

2.3. Awareness as a Jumping Octopus

'The mental activity is like a jumping octopus in a pile of rags', says Naur (2000) and continues to illustrate the dynamics of thinking:

> 'This metaphor is meant to indicate the way in which the state of consciousness at any moment has a field of central awareness, that part of the rag pile in which the body of the octopus is located. The arms of the octopus stretch out into other parts of the rag pile, those parts presenting themselves vaguely, as the fringes of the central field. […] The jumping about of the octopus indicates how the state of consciousness changes from one moment to the next.'

The rags of the pile may through focusing come to the field of central awareness. Here associations play a central role. On this Naur (2001, p. 11), summarizes from James:

> 'One object of thought is replaced habitually by the next. We say then that the two thoughts are associated or that the next thought appears through its association to the first one. [...] [W]hat enters into the association of thoughts is not elementary 'ideas', but complicated thought objects which are experienced as wholes but each of which includes more central parts and a fringe of vague connections and feelings.'

Associations may happen by contiguity and by similarity. Association by contiguity is essentially a matter of habit formation. James (1890, vol. I, p. 561) says:

> '[...] objects once experienced together tend to become associated in the imagination, so that when any one of them is thought of, the others are likely to be thought of also, in the same order of sequence or coexistence as before. [...] it expresses merely a phenomenon of mental habit, the most natural way of accounting for it is to conceive it as a result of the laws of habit in the nervous system.'

Association by similarity is (Naur 2001, p. 12):

> '[…] association between thought objects that have become connected in the thought merely by having the same abstract property in common, in other words by being similar in some respect.'

Association by similarity plays an important role in reasoning. Reasoning is concerned with solving problems, or answering questions, related to situations involving certain known things, having certain known properties, in which the person cannot reach the solution or the answer by direct association from the known properties. James explains how successful reasoning builds upon the person's noticing and attending to certain definite properties of the situation at hand, to wit such properties that point to a way of reaching the goal by direct association. James makes clear how reasoning in this sense is a decisive factor in human inventiveness and discovery, including that of scholars and scientists.

2.4. Utterances as Splashes over the Waves

'A person's utterances relate to the person's insights as the splashes over the waves to the rolling sea below', says Naur (2000) and continues:

> 'This metaphor is meant to indicate the ephemeral character of our verbal utterances, their being formed, not as a copy of insight already in verbal form, but as a result of an activity of formulation taking place at the moment of utterance.'

The metaphor also emphasizes how utterances are incomplete expressions of the complexity of a person's current mental object, in the same way as the splashes tell little about the sea below.

2.5. Human Knowing as a Site of Buildings

Human knowing is like a site of buildings in an incomplete state of construction, developed through maintenance and rebuilding. In Naur's (2000) formulation:

> 'A person's insight is like a site of buildings in incomplete state of construction. This metaphor is meant to indicate the mixture of order and inconsistency characterizing any person's insight. These insights group themselves in many ways, the groups being mutually dependent by many degrees, some closely, some slightly. As an incomplete building may be employed as shelter, so the insights had by a person in any particular field may be useful even if restricted in scope. And as the unfinished buildings of a site may conform to no plan, so a person may go through life having incoherent insights.'

3. Using the Metaphors

Below we show how the metaphors can describe human-computer interaction phenomena known from research and commonly available user interfaces. For each metaphor, we describe examples that are coherent or in conflict with the metaphor, and an example where a notion commonly used in HCI with the aid of the metaphors appear to us as described simpler and clearer.

3.1. Habit in HCI

There is an abundance of examples of user interfaces that violate human habits. For example the adaptive menus as used in Microsoft Office 2000. Adaptive menus change the layout of the menu according to how often menu items are used, for example by changing the position or removing items seldomly used. However, adaptive menus make it impossible to form habits in the selection of menu items (Raskin 2000), since their position may be different from when they were previously selected. Somberg (1987) showed the efficiency of constant position placement of menu items compared to menus that change based on use frequency. Somberg, however, did not explicitly link habit formation to the usefulness of constant placement of menu items. Note that the common practice of adding a fixed number of, say, recently used files or fonts to the bottom or top of a menu does not interfere with habit formation and may decrease time taken to select a menu item (Sears & Shneiderman 1994).

The discussion of consistency in user interfaces may be illuminated in terms of habit. In a classic paper on consistency (Grudin 1989), Grudin argues that focusing on consistency per se leads to a lack of focus on users and their tasks. He shows how consistency can be interpreted in different ways and how different aspects of usability contradict each other in what some call consistent designs. Actually,

Grudin's critique of the notion of consistency concerns the role of habit in the interface. With a focus on habits, the aim of consistency is to allow the habits that users develop to be transferable within or between systems they use. In addition, a system should also allow effective habits to be established in the first place, especially for often-used functions. Consistency between systems is not critical if interface elements or functions are not a habitual part of the users' repertoire of actions. Habitual association of words, however, might be useful for grouping or naming interface elements.

The central design issue with respect to consistency, and thus habit formation, is whether to utilize existing habits in the design of the system or create new ones. Grudin's (1989) discussion of choosing effective keyboard layouts (e.g. QWERTY or DVORAK) is an example where it is essential for users to establish effective habits, rather than transferring real-world habits (such as associating letters in alphabetical order) to the interface. One reason why consistency is a problematic notion is that it obscures long-term usability—especially the efficiency gained by supporting inattentive, i.e. habitual, use. Perhaps designers in HCI more often should aim for establishing new, effective habits. Even the most radical changes of interfaces may be mastered if the interface is used often. An analogue of this is shown in Stratton's experiments with glasses that turned his visual field upside down (Gregory 1997). When wearing the glasses constantly, in less than 7 days he had become habituated to viewing the world upside down and could walk, write, etc.

An example of a user interface that exploits that habit formation is not always wanted, is found in the evaluation version of the compression utility WinZip (www.winzip.com). When WinZip is run, an initial screen with five buttons is shown. Three buttons allow the user to get access to license information, to a screen for registration, and to information about how to order. The last two buttons are of interest here. One button quits the utility; another lets the user proceed to the main screen of WinZip. To prevent users from going straight to the main screen, the designers of WinZip randomly interchange the position of the two buttons when the utility is run. Effectively, this prevents the user from establishing a habit of clicking the proceed button without noticing the license and ordering information on the initial screen.

Walker et al. (1998) compare two different designs of a spoken language interface to email: (a) a mixed-initiative dialogue, where the users can flexibly control the dialogue, and (b) a system-initiative dialogue, where the system controls the dialogue. The results show that even though the mixed-initiative dialogue is more efficient, users prefer the system-initiative dialogue. This result was contrary to the authors' initial hypothesis. A correlation analysis with user satisfaction as the dependent variable uncovers how:

> ‘Users' preferences are not determined by efficiency per se, as has been commonly assumed. One interpretation of our results is that users are more attuned to qualitative aspects of the interaction.’, (Walker et al. 1998, p. 587).

The number of automatic speech recognition rejects contributed the most to user satisfaction. Walker et al. suggest that the users' preference for the system-initiative dialogue arises from it being easier to learn and more predictable. If focusing on habit formation, it would be immediately clear that the unpredictability of rejects in the mixed initiative dialog is damaging. Even though the system-initiative dialogue requires a larger number of dialogue turns, this interface is preferred because it better supports habit formation.

3.2. Stream of Thought in HCI

A simple, yet effective, attempt to recreate part of the richness of the stream of thought when users return to resume interrupted work, is Raskin's design of the Canon Cat (Raskin 2000). When the Canon Cat is started, the display immediately shows up as it was before work was suspended. Not only does this allow the user to immediately start thinking about the task at hand. It also provides help in remembering and recreating the stream of thought as it was when work was interrupted.

The fragility of the stream of thought is not well protected in many user interfaces. E-mail notifications, instant messengers, news on demand, and automatic spelling corrections are useful at times, but may also disrupt concentrated work. Research on instant messengers, for example, has documented the harmful effects of interruptions on task completion time (Cutrell et al. 2001). As a

personal note, one of the authors of this paper has recently removed all notifications of arriving e-mails from his computer. Even the .5 cm x .5 cm icon in the lower right corner of the screen that show the arrival of new e-mail could create an intense feeling of urge to check the e-mail—which would initially be in the fringe of the current object of attention, but eventually would lead to start of the e-mail program. This seemed especially to happen when that author was struggling with a difficult task. We find that most user interfaces fail to support shifting between what we experience as two phases of work: concentrated working, where interruptions and distractions are detrimental, and explorative working, where a free flow of associations, inspirations, breaks, and even interruptions can be useful.

An example of the dynamics of thinking that is closely related to the stream of thought is found in information retrieval studies concerning changes in relevance judgments of documents. One study (Eisenberg & Barry 1988) showed that the order in which subjects viewed document descriptions influenced the subjects' perception of the relevance of those descriptions. While this effect in part may be due to the categorical rating scales used, a psychological explanation is also possible. When looking at document descriptions, the themes of the previous descriptions will be in the fringe of the subject's mental object. Those fringes will influence the perception of the task and the judgment of the current document description. Thus, different orderings of documents will give different relevance judgments. The study also describes how significant differences in relevance judgments can be found even between random orderings of the documents to be judged. Thus, relevance judgments seem to be dynamic in a sense closely related to the metaphor of the stream of thought.

3.3. Awareness in HCI

The metaphor of the octopus can be illuminated by recent studies of awareness, e.g. Grudin (2001) and Greenberg & Rouding (2001). Common to these studies is an aspiration to design for peripheral awareness, to design also for the fringes of the octopus so to speak. As an example consider Grudin's study of how multiple monitors are used (Grudin 2001). Grudin found that among 18 users who used multiple monitors simultaneously, the multiple monitors were not used as additional space, but to partition the information used. Users would for example delegate secondary tasks such as debugging windows in a programming environment to the second monitor, and some users would have e-mail, news alerts, and instant messengers on the secondary monitor. Grudin's study is coherent with and supportive of the metaphor of awareness in two important ways. First, users employ the degree of attention they give information as a principle for dividing their work between monitors. Less important information is in the periphery of the eye and thereby to some extent in the fringes of the current mental object. This may reflect how subject introspectively realize that some information sources may in subtle ways distract us, but that they may be useful for creating fringes. Second, Grudin's work and other recent papers on awareness show opportunities for designing for peripheral attention and even in-attentive use of computers (Strøm 1996). It is evident from the metaphor of the octopus that the fringe of mental objects form a large part of our thinking and this should be taken into account when designing.

The characteristics of awareness and the association of objects thought of with other objects are not unfamiliar descriptions of human thought in HCI. Vannevar Bush's vision of the Memex (Bush 1945) may exemplify this:

> 'When data of any sort are placed in storage, they are filed alphabetically or numerically, and information is found (when it is) by tracing it down from subclass to subclass. It can be in only one place, unless duplicates are used; one has to have rules as to which path will locate it, and the rules are cumbersome. Having found one item, moreover, one has to emerge from the system and re-enter on a new path.
>
> The human mind does not work that way. It operates by association. With one item in its grasp, it snaps instantly to the next that is suggested by the association of thoughts, in accordance with some intricate web of trails carried by the cells of the brain. It has other characteristics, of course; trails that are not frequently followed are prone to fade, items are not fully permanent, memory is transitory. Yet the speed of action, the intricacy of trails, the detail of mental pictures, is awe-inspiring beyond all else in nature. Man cannot hope fully to duplicate this mental process artificially, but he certainly ought to be able to learn from it.'

However, as pointed out by Wendy Hall at the Hypertext'01 Conference, links that take the user to web pages associated with the link description are fairly uncommon at the web (Hall 2001). In hypertext research, such links are called associative or referential links (Conklin 1987), as opposed to for example navigational or organizational links. According to Hall, less than 1% of links on the World Wide Web are associative: the rest are predominantly navigational links. On one side this suggests that Bush's warning has been taken seriously—human awareness and association are not directly modelled on the WWW. On the other side, we feel that the lack of associative links might suggest that designers have paid too little attention to awareness, associations, and how to craft links that use this fundamental trait of human thinking.

As an example of a notion in HCI that may become clearer from the metaphor of the octopus, we would like to briefly discuss information scent. Information scent refers to (Pirolli & Card 1999):

> '… the (imperfect) perception of the value, cost, or access path of information sources obtained from proximal cues, such as bibliographic citations, WWW links, or icons representing the sources',

In HCI this notion has recently received much attention in relation to web design (Card et al. 2001). From our perspective, information scent is the ability of proximal cues to create in the mind of the user associations related to the content looked for. The degree to which WWW links or icons have 'information scent' is only a matter of the associations they create for individual users. In some studies of information scent, e.g. Pirolli et al. (2000), an information scent score is developed. Subjects are given the top levels of a hierarchical link structure and the information scent score is the proportion of subjects who correctly identify that a certain link contains the answer to some task. Thus, subjects assess the links from the associations created in relation to the task. The second aspect of the definition of information scent—the cost of accessing information sources—is related to habit. We most often follow our habits in traversing information structures rather than pondering the cost of certain ways of navigation. Thus, information scent is adequately described by the metaphors of awareness and habit.

3.4. Utterances in HCI

One consequence of the metaphor of utterances as splashes over the ocean is that we must expect users to describe the same objects and functions in an application program in a variety of ways. Furnas et al. (1987) investigated the diversity in words used for describing commands and everyday objects. On the average, two participants described the same command or object by the same term with less than 20% probability. The most popular name was chosen only in 15-35% of the cases. Furnas et al.'s suggestion for relieving this problem is called the unlimited alias approach. Instead of using a fixed set of words for commands and functions, the unlimited alias approach lets users enter any term they want. If the term is not in the range of terms initially suggested by the designer of the system—which the data of Furnas et al. and the metaphor suggest it often will not be—the system may interactively suggest appropriate commands or object names. This approach is coherent with the metaphor and uses interactivity to clarify the intentions of the user.

Examples of user interfaces that do not respect the metaphor of utterances are plentiful. Many of these involve systems that try to predict, given a few utterances, the needs and wishes of the user—something that is unlikely to succeed given the ephemeral and incomplete nature of utterances. One example is the attempt of the Office Assistant in Microsoft Word to infer which kind of document the user is writing given one or two words.

We believe that the relation between queries made on the WWW and what users are looking for may be made easier understandable by use of the metaphor. Queries on the WWW are on the average 2.2 words long (Jansen et al. 1998). However, such short queries cannot possibly reflect all aspects of the pages users are looking for, nor can they reflect the myriads of interests, questions, etc. that may suddenly become the locus of attention when triggered by otherwise irrelevant web pages. In information retrieval, the difficulty in interpreting the intention (or information need) behind the queries has long been recognized as problematic, as have the difficulty of expressing one's information need in the first place (Bates 1989). Harter (1992) has gone as far as to suggest that the information need is indeed our full mental constitution—which is impossible to express in a few words or queries. This is in accordance with the metaphor of utterances as splashes over the ocean and respects the complexity of mental objects, as described by the stream of thought and the octopus metaphors.

3.5. Human Knowing in HCI

One example that shows how effective it can be to respect the incomplete and developing character of human knowing, is found in object oriented programming, for example in the class libraries sometimes used to support development of user interfaces. Users of class libraries do not have to know the internal workings of the classes. Thus, they can program without a complete understanding of the classes they use and gradually build up an understanding of how the class works, should that be necessary. The intuition from the metaphor would be that object oriented programming would give a faster and broader understanding of the program. A recent study (Corritore & Wiedenbeck 2001) treats differences of program comprehension during maintenance between 30 expert programmers of object oriented and procedural languages. The study suggests that the initial phase of program understanding is easier in OO programming languages because programmers gradually build their understanding from partial insights about a large part of the program (Corritore & Wiedenbeck 2001, p. 1):

> 'The OO programmers tended to use a strongly top-down approach to program understanding during the early parts of familiarization with the program, but used an increasingly bottom-up approach during the subsequent maintenance tasks. The procedural programmers used a more bottom-up orientation even during the early phase, and this bottom-up approach became even stronger during the maintenance tasks.'

However, the study also suggests that eventually both the OO and the procedural programmers built a systematic understanding of the program.

Examples where the metaphor of a person's knowing is not respected are easy to find. Systems that require a full understanding of the system before they may be used are cases in point. An example is described in Chen & Dhar's study (Chen & Dhar 1990) of an online library catalogue. They observe how 30 subjects take wrong actions in using the system, how they use wrong query terms, and how they use sub-optimal procedure for accomplishing tasks. The faulty actions arise from the subjects' misconceptions about the topic they are searching for, about the way the online catalogue works, and about the nature of the classification system used. Each subject displayed at least one misconception. First of all this shows that even for a common task like searching a library system, the subjects' knowing about the program was incomplete. Second, Chen & Dhar's results show that the design of the online catalogue violated the metaphor of the site of buildings in several ways. As one example, the system only recognizes official Library of Congress subject headings, which in essence requires the subjects to have a complete and precise understanding of how their problem relate to the official terms. The lack of support for cross-referencing and inferring correct headings worsen this.

Mental models have been extensively discussed in HCI. Consider Norman's (1983) description of the use of calculators. He argues that the use of calculators are characterized by users' incomplete understanding of the calculators, by the instability of the understanding, by superstitions about how calculators work, and by the lack of boundaries in the users' understanding of one calculator and another. These empirical observations by Norman are coherent with the ideas expressed by the metaphor of knowing. In summary, the OO programming example, the library catalogue, and the use of calculators show that users solve the actual tasks despite inconsistencies and incompleteness of their knowing. Conversely, systems that require a precise and complete understanding are awkward to use.

4. Discussion

The aim of the paper was to describe HCI issues in the context of human thinking. We have not attempted to provide novel designs—readers with this interest should consult Raskin's work (Raskin 2000) for examples. More systematic exploration of the possibilities in design of using descriptions of the human thinking activity is desirable.

For evaluation, one idea would be to develop from the metaphors a usability evaluation approach, similar to expert inspection techniques such as heuristic evaluation (Nielsen 1993). Compared to heuristics and guidelines, the metaphoric descriptions perhaps support evaluators better in creating design ideas and envisioning the users' mental activity. Further, the metaphors may serve to uncover certain types of usability problems not found with traditional evaluation methods. Such problems might concern how well the interface supports habit development, the use of utterances in the

interface, and the associations created by functions and descriptions of commands. However, to investigate the viability of this idea a series of experiments are needed.

We are concerned that readers at this point consider this description of human thinking to be mainly common sense. But use of descriptions of human thinking is rare in much mainstream HCI literature. To give an indication of this, we examined five years of proceedings from a large conference on HCI, the ACM CHI Conference (see table 1). The table shows the number of papers that contains words describing human thinking in either titles, keywords, or abstracts (as found by searching ACM's Digital Library, September 2001). Numbers in parenthesis show the number of papers with only non-psychological uses of the word, as in '…little is known about…'. We find it striking how e.g. thought and knowing/knowledge—important terms describing human thinking in both psychology and everyday language—are virtually absent from the CHI Conference Proceedings.

Our readers may also be concerned that previous use of descriptions of human thinking in HCI suffices. However, the metaphors offer a high-level description of aspects of human thinking, whereas cognitive models commonly discussed in HCI, e.g. GOMS (Card et al. 1983) or Interacting Cognitive Subsystems (Barnard et al. 2001), build upon detailed descriptions of the operations and goals involved in solving tasks. Therefore, the metaphors may more conveniently help focus on human thinking, from early designs through evaluation to implementation.

Table 1—Number of papers in CHI Proceedings 1997-2001 that in titles, keywords, or abstracts use words describing human thinking.

Word	*CHI 2001*	*CHI 2000*	*CHI 99*	*CHI 98*	*CHI 97*
Habit/automaticity/automatization	0	0	0	0	0
Thought/Thinking/Think	2	2	0	1	0
Association	0	0 (1)	0	0	0
Awareness/Aware	6 (1)	3 (1)	4 (1)	3	2
Utterance	1	0	0	0	0
Knowing/Know/Knowledge	3 (4)	2 (6)	2 (1)	0 (1)	1 (3)

5. Conclusion

General properties of thinking activity known to all of us by introspection were emphasized through five metaphors, which build upon the work of William James and of Peter Naur. The metaphors catch psychological aspects of habit formation, stream of thought, awareness, utterances, and knowing. With the possible exception of awareness, these aspects of human thinking are rare in recent years of HCI literature. From commonly available user interfaces and from a selection of empirical studies, the utility of the metaphors was illustrated by their ability to clarify designs and notions in HCI. We suggest that the metaphors, by virtue of their psychological recognizability and focus on basic aspects of thinking, can help designers consider important human traits.

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