Invited Paper

Intuitive engineering, human factors, and the design of future interfaces

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ABSTRACT

Human factors engineering (HFE) professionals complain that they are often called in after-the-fact to help correct human interface problems. They believe many design flaws can be avoided if design teams involve them early on. However, in the case of innovative technology, such post hoc human factors may not be avoidable unless the inventor is also a human factors engineer or the prospective user. In rare cases an inventor of a new technology has an intuitive understanding of human engineering principles and knows well the capabilities and limitations of operators. This paper outlines the importance of focusing on the user-system interface and encouraging engineers to develop their own intuitive sense of users through mental imagery. If design engineers start with a clear mental picture of a specific user and task rather than generalities of use, fewer interface problems are likely to be encountered later in development. Successful technology innovators often use a visual thinking approach in the development of new concepts. Examples are presented to illustrate the successful application of intuitive design. An approach is offered on how designers can improve their non-verbal thinking skills. The author shares the view that the mission of HFE should not be to make system developers dependent on the small community of HF experts but rather to help them learn the value of applying user-centered design techniques.

Keywords: Interface design, human factors engineering, intuitive engineering, mental imagery, visual thinking

1. INTRODUCTION

Human factors engineering (HFE) professionals complain that they are often not consulted early enough in the development cycle of a new product or system. They report being approached only after the engineers or development team encounter user acceptance or system performance problems.[1] Thus, HFE specialists tend to voice the Rodney Dangerfield lament, as paraphrased by William Howell in his HFES presidential address, "We get no respect."

But the question might be, how soon in the development cycle can the HFE practitioner be reasonably brought in? While most HFE professionals would like to be involved at planning stage or start of the design phase, this rarely happens. Early involvement of HFE should be expected in large institutions where they routinely set up multidisciplinary development teams. However, there are circumstances involving individual inventors or small engineering teams where HFE is not, or could not be an early concern. In circumstances where engineers are inventing a technology the main consideration is on invention or novel variation of a technology with only a vague or general idea of application. In these situations we are usually dealing with revolutionary and not evolutionary technologies. It is, perhaps, only after solving some of the technical challenges that issues of human use and acceptance come to the fore.

Thus, in the case of innovative technologies, after-the-fact human factors may not be avoidable unless the inventor is also a human factors engineer or someone who is sensitized to the user-centered design perspective. In instances where the inventing engineer is in fact the user, there is a reasonable chance the product will have a user- friendly interface. Here, the engineer is naturally positioned to apply the HF dictum "Know Thy User". But even here the designer may not be sensitive to the limitations of the novice.

The most problematic circumstances are when product designers and program managers are experts in the technology area but are not among the population of users. If these technical experts are also not inculcated in the art and science of HFE, there is a reasonable chance the resulting product will encounter significant user interface problems. In such cases,

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a technology may be conceived or promoted by program managers and development teams who understand the fundamental technology but only superficially understand those who are expected to use it and the tasks they perform.

This paper outlines an approach to help technology engineers incorporate the user-task perspective into their product conceptualizations and development. The approach is easy to apply and involves the art of visualization or mental imagery frequently used by successful product innovators. This paper combines ideas from research on imagery, naturalistic decision-making, and sports psychology. Discussion begins with background on design philosophy and the art and application of non-verbal thinking.

2. BACKGROUND AND THESIS

Henry Petroski, the well know writer of popular books on engineering, argues that there is no perfect design. He states, "The ultimate context of design is, of course, the human user. Many designed things are 'one size fits all,' and so if they fit anyone perfectly, it is a statistical coincidence.... so, all the rest of us must make do".[2] While it is true no design is perfect for all potential users, it may be wrong to assume that something should be designed at the start for a general user. It may be a false hope that the product will, by chance, fit some users fairly well and others will be willing to make accommodations.

The problem of designing for general users from the start is that the resulting product may never identify a particular operator who finds it very easy to use or even useful. Without knowing a specific user with a specific application or task to perform it will be hard to establish interface design specifications. For example, if dealing with information displays and input-output controls, how does one decide the configuration of displays and input-output (I/O) devices? If we give the system a mouse I/O, can the individual use his or her hands while performing the task? If we chose to have a head-mounted visual display for the system, will a particular user be able to look at the display while performing the task? If the system uses voice control, will a user be able to talk to the system in every situation?

In answer to these questions most HFE experts will tell you that a user task analysis should be performed at the start to identify critical design specifications for the system (A particularly useful model that addresses these key issues is the Multiple Resource Theory, see Wickens, 2002).[3] Thus, the professional recommendation would be to "Start specific and end general". In other words, the expert would start by considering a specific user and application and only later modify the design for other potential users. As the system evolves to accommodate different functions and users it then becomes a general purpose system that is better able to handle a wide variety of users and applications. This usually leads to a system that is re-configurable, adjustable, or has options for different users and tasks.

The recommendation to design for a specific user directs us toward making sure we clearly identify the user and task. Some successful innovators have spent considerable time contemplating particular users (usually themselves) and imagining how they might use a device in specific settings. Jeff Hawkins, creator of the PalmPilot (now PalmOne) and later the Visor (Handspring) PDAs, used a wooden block for mentally experimenting with his design ideas. In developing features for the Visor, for example, he imagined a handheld that could become a smart phone by inserting an expansion module. But he wasn't sure holding a PDA up to one's face would feel natural. So he tried it with his block of wood:

> "I'd go around the office answering phone calls on this block of wood," he said. "It felt OK. ...That's why the Visor has a microphone." People had their doubts about the smart phone idea, he said, "but I already knew it would be OK because I tried it.".[4]

Interestingly, when he did the same thing to "think through" using voice control as an I/O for the PDA the same mental simulation process lead him to conclude voice operation of these devices would not work, even though others were spending lots of time and money on this capability. Thus far the market seems to have proven him right. By using mental simulation Hawkins developed and used his intuitive sense of what various capabilities might mean to users in different situations.

3. MENTAL IMAGERY AND ENGINEERING

In the case above, Jeff Hawkins spent some time imagining, not in vague terms but in detail, users in specific ways. The idea that mental imagery is a form of thinking for problem solving has a long history. In 1883 Sir Frances Galton conducted surveys to test people's ability to use imagery. Galton found that many people use imagery as a form of thinking while others claimed they do not. Recent research suggests mental imagery is a form of thinking most, if not all, of us use whether we are aware of it or not.[5] While people may differ in their ability to evoke vivid imagery, studies suggests the skill can be improved with practice.[6] Engineers, however, may not see visual thinking as a tool of their trade and thus may pay little attention to its potential. In fact, not until fairly recently have engineers been encouraged to use non-verbal ways of thinking or to develop and use intuition or "the mind's eye" in their work.

> "Since World War II, the dominant trend in engineering has been away from knowledge that cannot be expressed as mathematical relationships. The art of engineering has been pushed aside in favor of the analytical "engineering sciences," which are higher in status and easier to teach.[7]

Ferguson argues that engineering schools too frequently ignore nonverbal learning and the use of mental imagery. Product engineers are "dangerously ignorant of the myriad, subtle ways in which the real world differs from the mathematical world their professors teach them". He speaks of the power of the mind's eye.

> "The mind's eye, the locus of our images of remembered reality and imagined contrivance, is an organ of incredible capacity and subtlety. Collecting and interpreting much more than information that enters through the optical eyes, the mind's eye is the organ in which a lifetime of sensory information - visual, tactile, muscular, visceral, aural, olfactory, and gustatory - is stored, interconnected, and interrelated".[7]

Our verbally dominated society often confuses thinking with the symbolic manipulation of language and mathematics. It is really much more than that, as was so well articulated by Ferguson above. In some extreme cases there are inventors who are almost totally visual in their thinking and find it difficult to use symbolic reasoning and language.

> "I THINK IN PICTURES. Words are like a second language to me. I translate both spoken and written words into full-color movies, complete with sound, which run like a VCR tape in my head. When somebody speaks to me, his words are instantly translated into pictures. Language-based thinkers often find this phenomenon difficult to understand, but in my job as an equipment designer for the livestock industry, visual thinking is a tremendous advantage".[8]

Many of the world's most notable scientists used imagery in what has been called the "thought experiment". Albert Einstein is said to have created "a great theater of thought experiments to explain relativity".[9] For his theory of relativity, the symbolic language of mathematics came later.

But imagery can be more than just a physical sensory-level experience like vision that comprises what we call the 'mind's eye'. Non-verbal thinking also works to help understand and deal with other more subtle aspects of life at the perceptual level. The ability to mentally simulate alternative actions (in multi-sensory mode) before selecting the right action is considered the skill of the expert.[10] Mental imagery is also a tool for perceiving context such as in social perception.[11,12] When we imagine how people might react to us when we use or wear something, as Hawkins did with the Visor, we are referring to what is more commonly called intuition. Such a perceptual level of imagery, it is argued, gives us our sense of self.

> "It is postulated that imagery internalizes this social mechanism because mental images empower us to literally see ourselves acting (or having behaved) in given ways as others could see (or have seen) us acting.".[12]

Similarly, athletes use imagery, although in a slightly different way, to train and to prepare for their sport. Athletes will tell you they think about their sport non-verbally. They report practicing with mental images to improve their concentration as well as to improve execution through image rehearsal:

"Mental imagery involves the athletes imagining themselves in a specific environment or performing a specific activity. .... They ..... attempt to enter fully into the image with all their senses (sight, hearing, touch, smell) and perform as they would like to perform in real life.".[13]

Coaches encourage athletes to develop and improve their visual-motor imagery.[6] The key guide to athletes is for them to initially pay close attention internally to their physical performance and the context of competition and then mentally review and rehearse their performance as often as possible. As the athlete's skill improves so does the imagery which in turn can be used to improve performance through mental practice or rehearsal.

4. APPLICATION

In the same way athletes or theoretical scientists use visual and motor imagery to think about their problem space, engineers can use and develop their visual-motor imagery, natural intuition, and understanding of human action and social dynamics from daily life. Engineers can think about and understand how users might respond to their technological innovations. Through a sort of mental role playing engineers can build detailed scenarios of users in action using a conceptualized product. In this way the engineer can begin to "see and feel" which features are likely to work and which will not.

Thus, imagery research suggest that the more one sees, interacts, and gets to know particular users, the easier it is to develop a sense or intuition about how a user will respond to envisioned interfaces.[14] Using mental imagery a design engineer can conceivably evaluate potential designs even before 'bending metal'. The secret of the approach is for the practitioner to obtain the necessary details about particular users and settings from which to develop the necessary imagery.

5. CONCLUSIONS AND DISCUSSION

Too often new technologies are developed with only a vague idea about application. Even though a general user and use may be considered early in the program, the details are often lacking. The necessary details are often left to human factors engineers who are called on the scene later to ensure that there is a good fit between user and system. But sometimes the concept is ill conceived and there is little that can be done to make it work for any particular user or task.

While it may not be feasible to have a trained HFE professional available during the early development of every new system, it may be possible to train more designers to apply their imagination to thinking about users early on. Rather than thinking of their design ideas as something for general application, the designer should begin by identifying a very specific user in a specific context. Being concrete and specific will make it easier to think in greater detail about the user-task dynamics and to evaluate the fit, feel, and function of someone using the product.

Knowing the particulars, the engineer can begin by using mental imagery much like athletes do to mentally practice or the way scientists do thought experiments to discover scientific principles. Examples have been presented above to illustrate how some innovators have developed successful devices, such as the PDA, by imagining themselves using the device in specific situations.

It should be pointed out that many HFE professionals may strongly disagree with this thesis arguing that the recommendations here go counter to basic teachings of human factors and ergonomics science. The concern of HFE practitioners is that design engineers may make the fundamental subjective error of assuming that they are like others, when they are not. To guard against this, HFE courses are taught on how to conduct user surveys, and evaluation tests on a representative sample population. Thus, the student of HFE is trained to avoid an egocentric view. The emphasis in the profession is to, instead, conduct empirical studies that avoids the inherent bias of subjective introspection.

Although the present author agrees, in principle, with this caution about the risks of egocentric subjectivity, there may be more value in advocating the use of mental imagery as a way to encourage engineers to look more closely at users and tasks. Since mental imagery works best if the person is able to observe and learn more detail about user and task, the engineer may then be lead toward devoting more time considering users than is typically the case. At the same time engineers will discover that imagery can be a powerful tool that is relatively easy to apply. The key, again, is to begin thinking of specific, not general, applications and in concrete product features, not the theoretical or symbolic language of engineering.

Thus, the approach beckons engineers to get to know the world through their senses (visual, auditory, tactile) and to attempt to learn to view things like the people who are likely to be system users. Some researchers refer to this as visual thinking but it is actually more than mere vision, it involves all the senses working together in what now is referred to as multi-sensory perception.[15]

Another objection to the theme of this paper might be that not everyone may be able to use mental imagery as suggested by Galton's findings. Research continues to hint that certain people claim not to be able to think with imagery.[13] This may be true, but probably only in degree. As science probes the brain it looks like thinking involves a combination of verbal and nonverbal processes and associations. People may differ in how much they utilize one form or the other when trying to solve problems.

Jeff Hawkins clearly uses concrete imagery more than the symbolic abstractions of a technical language. His insights appear to come from common everyday experiences with 'things'.[16] So given that individuals may differ only in degree in how much they use one mode or the other it may be reasonable to assume most people could enhance whatever ability they have to utilize non-verbal thinking with a little training. This is the position taken by many sports psychologists who are involved in imagery training. This is the position of this author who encourages engineers to spend more time trying to know and understand users and what they are expected to do. There should be great benefit in getting engineers to develop mental imagery about users that should help us all address the important issues of the human-interface of future systems.

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