HUMAN TECHNOLOGY

An Interdisciplinary Journal on Humans in ICT Environments ISSN: 1795-6889

www.humantechnology.jyu.fi Volume 5 (1), May 2009, 90–113

MENTAL MODELS, MAGICAL THINKING, AND INDIVIDUAL DIFFERENCES

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Abstract: *Broadly, there are two mutually exclusive accounts of how people (non-specialist users) reason about and conceptualize interactive technology. The first is based on classical cognitive psychology and is characterized by the term* mental model. *The second, drawing on concepts from social cognition, observes that people often anthropomorphize technology. We argue that people are able to exhibit both of these quite different styles of cognition, which Baron-Cohen has described as systemizing and empathizing. The former is associated with the drive to analyze, explore, and construct a system, whereas the latter is the ability to spontaneously tune into another's thoughts and feelings. The propensity to systemize might give rise to a mental model, while the empathizing tendency might tend to anthropomorphize technology. We present an empirical study that lends support for the above position.*

Keywords: *human–computer interaction, cognitive style, mental model, anthropomorphization.*

INTRODUCTION

Interactive technology is one of the defining characteristics of modern society, and how we design, use, and think about it is, consequently, of considerable importance. To this end human–computer interaction (HCI) is a multidisciplinary field that has drawn on psychology, software engineering, anthropology, sociology, and philosophy. Indeed, in the preface of the first great HCI text, *The Psychology of Human-Computer Interaction* (Card, Moran, & Newell, 1983), we find, "The domain of concern to us, and the subject of this book, is how humans interact with computers. A scientific psychology should help us in arranging the interface so it is easy, efficient and error free" (p. vii). Recalling the early days of HCI, Carroll (2003, p. 3) observes that, "the initial vision of HCI as an applied science was to bring cognitive-science methods and theories to bear on software development." In due course, Card and his colleagues went on to propose the model human processor (as a means of modeling

URN: NBN:fi:jyu-20094141412

how people reason about and use technology) and to create an essentially task-based approach to the design of the user interface. This dual use of cognition has remained with us to this day.

Some 20 years later, HCI has successfully developed numerous cognitive models and psychologically plausible engineering models of human behavior (Gardiner & Christie, 1987; Hollnagel & Woods, 1983; Payne, 1991) that, to a greater or lesser extent, have proved to be able to model aspects of the behavior of people using interactive systems and devices. Strongly predictive models, such as the keystroke-level model (Card, Moran, & Newell, 1980), have, for example, been used to predict the time to complete a task for a skilled individual, while cognitively inspired tools like GOMS (goals, operators, methods and selection) have been used in the design and evaluation of user interfaces (John & Kieras, 1996). This "golden age of HCI" (Carroll, 2003) has also witnessed the adoption of mental models as a means of accounting for how we learn to use and conceptualize interactive technology (e.g., Gentner & Stevens, 1983; Norman, 1983). The term *mental model* first appeared in Craik's *The Nature of Explanation* (1943) and then reappeared in the 1980s, as Johnson-Laird (1983) and Gentner and Stevens (1983) independently adopted the term to describe complex cognitive representations. These models are very diverse and include systems (e.g., our knowledge of banking), devices (e.g., the operation of pocket calculators), physical forces (e.g., the nature of electricity), or a concept (e.g., the administration of justice). HCI mental models also have had the dual role of being used to reason about how to create an interactive system and as a means to represent people's understanding of a particular interactive device or system (e.g., Norman, 1983).

While subsequent research has moved beyond this exclusively cognitive stance (discussed below), there remains the assumption that cognition (mental models in particular) still has a role in how people use interactive technology. However a recent report in *New Scientist* magazine (Marks, 2008) reminds us of another aspect of our cognition that manifests as a tendency to treat inanimate objects like pets or even friends. The magazine cites a report of people's interactions with *Roomba,* a robot vacuum cleaner.[1] It was reported that some of the owners of this vacuum cleaner dressed it up, assigned it a gender and even gave it a name. It is suggested that this kind of behavior is commonplace. Indeed, a decade or so earlier, Reeves and Nass (1996) presented evidence that users treat computers, television, and other new media as though they were people, that is, response to or interaction with them is primarily social. We are, for example, polite (and rude) to interactive technology and these responses, they suggest, are the products of our "old brains" being misled amid the glamour of these new media. They also argue that media representations and techniques have been progressively designed over time specifically to activate these very social responses. For the purposes of this discussion, and in keeping with more recent research, we will characterize these descriptions as *anthropomorphic accounts* that arise from aspects of our social cognition.

So it appears we are potentially faced with a dichotomy. Either people conceptualize interactive technology by way of a mental model, which is characterized as set of processes that can be modeled, or as a friend—"superstitious" in character and comprising "magical thinking"—that is, ascribing agency, feelings, and intentions to technology. However, it could be both. Our treatment of this mismatch is to recognize that these two views reflect two distinct cognitive styles that appear to correspond with the distinction Baron-Cohen (1995, 2002, 2004) has named *systemizing* and *empathizing* cognition. Systemizing cognition is

associated with the drive to analyze, explore, and construct a system and, as such, is a candidate for the mechanism (or mechanisms) responsible for creating a mental model. Empathizing cognition, in contrast, is the ability to spontaneously tune into another's thoughts and feelings. Empathizing cognition is closely related to what has been called theory of mind (Premack & Woodruff, 1978) and may be the source of our tendency to treat technologies as though they have thoughts, feelings, moods, and desires of their own. Baron-Cohen also has shown that this is not an either-or situation, but rather individuals having both abilities in different proportions. This observation may allow us to account for people being able to hold both positions with respect to interactive technology.

COGNITIVE ACCOUNTS, RATIONALISTIC APPROACHES

Most of the work on mental models was conducted in the 1980s and 1990s, but began to lose favor when a raft of new concepts in human–computer interaction appeared. Cognition itself is now recognized as being situated (e.g., Suchman, 1987), distributed (e.g., Hutchins, 1995; Hollan, Hutchins, & Kirsh, 2000), external (e.g., Scaife & Rogers, 1996), embodied (e.g., Clark, 1997; van Dijk, 2009, this volume; Valera, Thompson, & Rosch 1991), and even collective (e.g., Engeström, 1987, 1999). Although classical cognition, as typified by Fodor (1983), no longer has as much currency as it once had, it has proven to be remarkably resilient, as the work we have just cited are extensions to cognition, not evidence of its abandonment. As for mental models themselves, Gillian Crampton Smith, the doyenne of interaction design, notes the importance of a good mental model in the design of interactive technology, in that, "we need a *clear mental model* of what we're interacting with" (Crampton Smith, n.d., cited in Moggridge, 2007, p. xv).

As we have already noted, mental model accounts have been used both to inform design and as an explanatory medium, though this has not always been made explicit. A consequence of this, although there are other contributory factors, is that there is no agreement on the precise nature, function, or composition of mental models. Indeed Rouse and Morris (1986, p. 360) have noted,

> At present, this area of study is rife with terminological inconsistencies and a preponderance of conjectures rather than data. This situation arises, to a great extent, because a variety of sub-disciplines have adopted the concept of mental models, and proceeded to develop their own terminology and methodology, independent of past or current work in this area in other sub-disciplines.

Mental Models as the Basis of the Design of Interactive Technology

From the design perspective, Norman (1983) introduced a number of different forms of mental model. The first is the user-constructed model of the computer system (the target system) with which he/she is interacting. The target system should be designed in such a way as to communicate its underlying *conceptual model*. Later he revised this account (Norman, 1986) so that the target system becomes the *system image* that includes the physical model of the system: input/output devices, documentation, training, error handling, and so forth. The conceptual model becomes the *design model* created by the designer, and the *user's model* is

now the result of interaction with the system image. Thus, good design is embodied and determined by the quality of the mapping between the system image and the resultant user's mental model. If the system image is not a clear reflection of the design model, then the user will end up with the wrong mental model.

Mental Models as the Basis of How We Reason about Interactive Technology

From the explanatory perspective, Young (1981, 1983), for example, explored a number of the properties of mental models through a series of empirical investigations. His studies investigated how people reasoned about the use of calculators. Of particular interest to Young were the role of analogy, the stability of mental models in long term memory, their propositional content, and the rules governing the operation (i.e., their "grammar"). Norman (1983, 1986) also concluded that (a) mental models are incomplete and unstable, since people forget details of the system; (b) people's abilities to "run" their models (in the sense of running an internal simulation) are severely limited and do not have firm boundaries; that is, similar devices and operations get confused with one another; (c) mental models are unscientific; and (d) mental models are parsimonious. People are willing to undertake additional physical operations to minimize mental effort; for example, people will switch off the device to reboot and start again rather than trying to recover from an error. Finally, Payne (1991) reported what he called a descriptive study of mental models. He recruited 16 participants who were interviewed about their beliefs and understanding of the mechanisms behind ATMs (automated cash dispensers). He was specifically interested in (and whether) people spontaneously create explanatory mental models about the ATM's operation. Following an informal content analysis of the resulting interviews, Payne observed that "it is clear that many subjects had already constructed mental models of bank machines—they had speculated about the inner working of the system in advance of being promoted to do so by a curious psychologist" (1991, p. 18). In all, he concluded that mental models can be used to predict behavior by means of "mental simulation," which in turn rely on analogy to function.

Despite the weaknesses of the mental model accounts of how people *think* about the operation of interactive technology, it is worth reiterating that no other widely held explanation has yet appeared to directly replace it, except, of course, when people think of interactive technology as their friends.

ANTHROPOMORPHIC ACCOUNTS

> The ascription of human-like characteristics to computing technology has become integral to our design, use, training, and communications with regard to computing technology and it has been argued to be the most common metaphor used in computing discourse. (Johnson, Marakas, & Palmer, 2008, p. 169)

Reeves and Nass (1996) were among the first to recognize that the way in which we treat interactive technology, television, and other new media is essentially social. In their *The Media Equation*, they show in a surprisingly wide variety of ways that the apparent blurring of real and mediated life is commonplace. They present evidence that we interact with media in the same

way we respond to other people, using the same rules that govern face-to-face interpersonal interactions. This equation is recognized as being particularly remarkable and counterintuitive, since people know that the medium they are interacting with is not a real person.

Interactive technology is, of course, distinguished from other technologies by virtue of its very interactivity, a trait it shares with humans. Computers also use language. Computers are instructed to perform by way of programming languages. HCI designers are concerned with dialogue design, that is, how the interaction between person and interactive technology is structured. Computers can produce human-sounding voices (Nass & Moon, 2000; indeed it has been noted by many that the only really human character in Stanley Kubrick's 1968 movie *2001: A Space Odyssey*, was HAL, the computer). Studies of social presence have revealed that users easily and regularly ascribe human characteristics, emotion, and behavior to avatars created within collaborative virtual environments (for a review, see Biocca, Harms, & Burgoon, 2003.) Perhaps most importantly, computers now fill roles traditionally held by humans. Computing technology is ubiquitous in our society, often mediating our basic daily interactions, such as communication, banking, paying bills and taxes, and governing much of our working lives. Winograd and Flores (1987) also have observed that computing technology has apparent autonomy, complexity of purpose, structural plasticity, and unpredictability—all of which are human-like characteristics.

Nass and Moon (2000, p. 86) have examined what they describe as the fundamental truth that "the computer is not a person and does not warrant human treatment or attribution." They point out that computers do not have faces or bodies—unlike, say, a child's toy—are unresponsive to human affect, and never express emotion themselves. Yet for all of this, there is abundant evidence that people mindlessly apply social rules and expectations to interactive media. In a series of experiments, they further found that people tend to "overuse human social categories" (p. 82), such as gender and ethnicity, politeness and reciprocity, and behave as though computers have personality traits, such as friendliness. People also have been found to use social rules and respond to computers with different voices (Nass & Steuer 1993), to feel psychologically close to or connected with a computer (Lee & Nass, 2005), to respond to computer personalities in a similar manner as they respond to human personalities (e.g., Brave, Nass, & Hutchinson, 2005), and even to respond to flattery from the computer (Fogg & Nass, 1997). Evidence shows that people with strong anthropomorphic beliefs are more likely to ascribe responsibility for their interactions with and outputs of a decision support system than those with weaker anthropomorphic beliefs, even though the ultimate interactions and decisions were within the control of all users (Johnson, Marakas, & Palmer, 2006). In all, there are fewer studies of this kind than the corresponding classical cognitive accounts and their findings are yet to be translated into design features. Nonetheless, their results are very robust. Next we consider these two different cognitive styles.

DIFFERENT COGNITIVE STYLES

Baron-Cohen's (1995, 2002, 2004) systemizing–empathizing account of psychological sex differences is based on neurological differences in "male" and "female" brains. While Baron-Cohen emphasizes functional and structural brain difference, we, like others (e.g., Focquaert,

Steven, Wolford, Colden, & Gazzaniga, 2007), are more concerned with the differences in the resulting cognitive style and their consequences for how people think about interactive technology. We approach this concept with some caution since we believe that this is first time Baron-Cohen's work has been applied to the domain of HCI.

Baron-Cohen claims that the female brain has a predominant propensity for empathy while the male brain is predominantly wired for understanding and building systems. In support of this position, he introduces evidence to suggest that male and female brains develop differently from conception. The source of these differences is the presence of prenatal androgens (male sex hormones) that can permanently affect the development of the neural structure and function of the brain. However, while male brains are more commonly found in men and female brains in women, this distinction is in no sense absolute. The propensity to analyze a system in terms of the rules that govern it in order to predict its behavior and the propensity to identify and understand the mental states of the other in order to predict his/her behavior, and to respond appropriately in either case, is found in both men and women (Baron-Cohen, 1995, 2002, 2004; Baron-Cohen & Wheelwright, 2004). Excepting a few extreme examples, no one would suggest that men are incapable of empathy, nor women incapable of understanding the workings of a system. Every individual has a propensity for each cognitive style in varying proportions.

Individual systemizing and empathizing quotients can be derived means of a pair of administered questionnaires that Baron-Cohen (2004) has developed (see Appendixes A and B). These questionnaires consist of 60 questions for either a Systemizing Quotient (SQ) or an Empathy Quotient (EQ), and are based on a Likert scale, with answers ranging from *strongly agree* to *strongly disagree*. The questions related to the SQ are of the form, "When I listen to a piece of music, I always notice the way it's structured" and "If I were buying a car, I would want to obtain specific information about its engine capacity," which are designed to capture a person's tendency to systematize. By contrast, the EQ questions are of the form, "I can easily tell if someone else wants to enter a conversation" and "I find it difficult to explain to others things that I understand easily, when they don't understand it first time" [*sic*]. Questions are scored 1 or 2 points on the respective scales, although there are also some null questions that afford no score. From the resultant scores, people can be categorized as high, average, or low empathizers or systemizers, remembering that the two scales are independent. These quotients can be interpreted using the guidelines, which may be found Table 1.

HOW PEOPLE THINK ABOUT THEIR MOBILE PHONES

Before describing the procedure we adopted, it is worth taking a moment to examine the methodology that inspired this work. It will be recalled (see Section 2) that Payne (1991) conducted a series of interviews with the intention of exploring the mental models people spontaneously create to mediate their interaction with technology. In his study, he interviewed people regarding their attitudes and understanding of ATMs. The interviews were conducted in an unrestrained manner. Payne's subsequent treatment of the data is not well documented but appears to be an informal content analysis.

Table 1. Interpreting the EQ and SQ Results (after Baron-Cohen, 2004, p. 216).

Empathizing Quotient (EQ)	
i.e., the ability to understand how other people feel and responding appropriately	
0-32	*Lower than average*
33-52	*Average ability*
53-63	*Above average*
64-80	*Very high ability*
Systemizing Quotient (SQ)	
i.e., the ability to analyze and explore a system	
0-19	*Lower than average*
20-39	*Average ability*
40-50	*Above average ability*
51-80	*Very high ability* (three times as many people with Asperger syndrome[2] score in this range compared to typical men, and almost no women score in this range)

Note: In the EQ scoring, most women score about 47 and most men score about 42, while in the SQ scoring, most women score about 24 and most men score about 30.

Research Questions

Modern mobile phones are no longer limited to simply making and receiving calls; they now routinely have a range of interactive functions and, as such, can be treated as interactive technology. Therefore, we propose that the SQ and EQ of the individuals in this study are indicative of their propensity to describe the operation of interactive technology (i.e., mobile phones in this instance) using language that is

- rich in technical, systemizing terms (for those with above average SQs), or
- filled with anthropocentric, empathizing terms (for those with above average EQs), or
- a mixture of technical and anthropocentric language (for those balanced in their SQ and EQ).

Although we have not proposed formal hypotheses for this study, it is worth considering the null, or alternate, hypothesis before proceeding to a discussion of the method. We have been careful to stress that while our research questions (described above) are indicative, myriad other factors may well mask these systemizing and empathizing propensities. While a formal experimental protocol may have been able to isolate and control for these factors, our interest was in (a) reproducing Payne's explicitly descriptive study, and (b) exploring the everyday, rather than the experimental, aspects of people using their mobile phones.

Method

Participants

In all, 16 males and 7 females agreed to participate. All were non-immigrant native English speakers. They were aged between 18 and 45 years, with median age of 22 years. These

people had been recruited from the postgraduate research students and undergraduates from the School of Computing at the Edinburgh Napier University.

Procedure

All 23 participants first completed the two questionnaires that measured their individual EQ and SQ. These were scored by the second author using the guidelines that accompany them. Of the 23 participants, 13 achieved balanced score (EQ = SQ, which we operationally define as EQ = SQ ±5), 4 achieved an above average score in empathy abilities (EQ>SQ) and 6 people scored above average systemizing abilities (SQ>EQ). On the basis of these results, 12 people (4 above average EQs, 4 above average SQs, and 4 balanced[3]) were randomly selected to participate in the interview portion of the study.

The selected participants were individually taken aside to a quiet room to be interviewed. The participants were asked to complete a consent form and were informed that the collected data would be transcribed, analyzed, and may be submitted for publication. The participants were assured that this was not a test of their knowledge, and they were not obliged to provide the interviewer with an answer. An audio recording, using a Sony DAT recorder, was made of the interviews. The interviews themselves varied in length from around 10 to almost 40 minutes (varying with the loquaciousness of the interviewee). The interview procedure was designed to constrain the interviewee as little as possible, although some limited prompts were necessary. All were also asked to demonstrate and talk-through the typical use of their mobile phones. Participants were encouraged to discuss how they used mobile phones and the role of this technology in their lives. A full list of questions asked of every participant can be found in Appendix C.

As in much qualitative research, content analysis is fundamentally interpretive, meaning is often implicit and can only be understood through deep and repeated familiarity with the entirety of each participant's interview protocol. What follows are both illustrative and representative of the participants' answers to two of the questions we posed. The quotations were selected by the authors to reflect the participants' cognitive style, that is, whether they tended to systemize, empathize, or give balanced answers.

RESULTS

The question "What is inside a mobile phone?" was so phrased to more likely prompt a technical answer. We expected that those individuals with relatively high SQs would offer detailed technical answers.

Above Average SQs (40–50)

Of six participants with high SQs, all but one provided highly technical answers; the other gave answers using systematizing language, although it was considerably less technical.

> *What's in the telephone? Ummh--lots of transistors and chips and things, and the battery,* [pause] *and* [pause] *liquid crystal display for the screen and the speaker, and the microphone, and the camera* [pause]. (Participant 1, SQ = 40)

> *Many things, circuit boards, chips, transceiver* [laughs], *battery* [pause], *a camera in some of them, a media player, buttons, lots of different things.* [pause] *Well there are lots and lots of different bits and pieces to the phone, there are mainly in ... Eh, like inside the chip there are lots of little transistors, which is used, they build up to lots of different types of gates and/or "x" these types of gates or electronic gates. There are resisters and diodes;* [pause] *there's a fair amount of copper on, I'd imagine, on circuit boards. There are lights, some of which are light-emitting diodes; in fact they are all probably light emitting diodes. There's a camera, as I have already said. There's a battery, and in most modern mobile phones they use lithium polymer batteries, um… because they last longer and have greater capacity….* (Participant 4, SQ = 44)

> *What is in the phone? Um, all kinds of circuitry and devices. I know there's a camera in the phone, so there will be a light detector for that. And there is a wireless card, so there's a wireless interface for that. There's a memory slot, so there will be an interface for that. There's a SIM card; the SIM card contains your personal information, it's a sort of chip that contains your unique identifier for the network, so basically your phone number and such. Uh, it has onboard memory for storage; it has onboard memory, volatile memory for operating system use, umm, and it has the various hardware that drives the screen.* (Participant 6, SQ = 45)

> *In... inside the telephone? Well, I mean it's ... eh ... you know, you're going to have a printed circuit board, known as a PCB. Ahh ... that ... that allows for communications between the different, ah ... chips on the PCB for things like voice encoding and decoding, umm... so I can hear and speak ahh ... with people. Umm ... This also allows for power to come from the battery to the different elements, umm ... and obviously to the screen as well.* (Participant 7, SQ = 50)

Average SQs (20–39)

Participants with average SQ scores tended to be less loquacious, saying less about what is inside their phones than those with higher scores.

> *What's* in *it? It's a little computer; it's a microchip, and a screen, and shit like that.* (Participant 8, SQ = 24)

> *No.* [laughs] *A speaker and a microphone and a camera, if you got a camera* [laughs], *phone umm ... and a battery and a SIM card. That's about all I know.* (Participant 10, SQ = 27)

There were no participants with low SQs in the sample with whom we could compare accounts.

How People Think Mobile Phones Work

Following Payne's protocol, we asked, "How do you think the telephone works?" with the coda, "Pretend you are answering to the intelligent Martian who has no experience with the devices."

Balanced Individuals (EQ = SQ ±5)

All participants with balanced EQ and SQ scores tended to give answers that contained strong evidence of neither systemizing nor empathizing elements.

> *Ok* [long pause] *Umm... Ok... I... I... I...think like, Mmmh ... of course it's working over satellite and, mmmh ... it's provided with software for the text messages, like that I can use T9 and stuff like that. And I think it's almost just based on software and this, umm … code is transferred over satellite.* [pause] *And the, the, the calling is just like with a normal phone but it's not transferred over a landline but over umm satellite, that's… yeah.* (Participant 11, SQ = 33**,** EQ = 38)

Participant 11, unlike those scoring above average on the systemizing scale, shows little or no evidence of having a detailed mental model of the phone's operation. Instead she describes the operation of a mobile phone coherently but in a high level, fairly general manner.

Above Average EQ (55–63)

All highly empathizing participants provided similar sorts of answers to the same question that tended to highlight the surface features of their phones.

> *It flashes the lights, screen flashes, and the buttons lights up, and it vibrates. It comes to life on the inside and it comes to life on the outside, and you talk to the one side and someone is answering on the other side* [long pause]. *Umm... well, all the different elements connect and work in the phone so enable you to … make the phone call. I don't know how, but yeah ... I don't know. It's a mystery. It's magical* [laughs]. *I have no understanding of how it works. So it really is magical.* (Participant 3, EQ = 55)

> [Interviewer] What happens if you enter your PIN code incorrectly?
> *Three times? It locks me out.*
> [interviewer] And what does it mean?
> *It means I can't use it and I cry quite a lot.* (Participant 8, EQ = 56)

For Participant 3, who shows above average empathizing propensity, the language is quite different from that of the other extracts. This participant ascribed agency to her phone ("It comes to life") and often referred to her phone as being magical.

Space prevents a fuller account of these interviews but what is clear is that there is a relationship (but not a simple one) between the systemizing quotients and the nature of the answers people gave. People with high SQs appear to have complex, well populated mental models of their phones; people with lower SQs less so. For those with high EQs, the picture is less clear. There is some evidence of anthropomorphism, but we suspect the demand characteristics of the situation may have obscured this. The balanced individuals are best characterized as being disinterested, with no real evidence of either systemizing or empathizing propensities.

DISCUSSION

As we have seen, there is a considerable body of evidence regarding how people reason about and conceptualize everyday interactive technology. We have argued that Baron-Cohen's

(1995, 2002, 2004) distinction between systemizing and empathizing cognition is used here differentially to create either mental model or anthropomorphic descriptions, as required. The data we have presented from the study of how people think about their mobile phones indicate that

- people who demonstrate high SQs tend to produce detailed, technical accounts of technology. This finding is consistent with the mental models hypothesis.
- people who demonstrate high EQs correspondingly show little technical knowledge and are given to describing the workings of technology in terms of magic and anthropocentricism.
- people who demonstrate a balanced EQ and SQ appear to offer explanations on how technology works that are neither overly technical nor anthropomorphic.

However a powerful factor in an experimental setting such as this is the way in which we posed the questions. Cognition cannot be observed directly, but the very ways in which we study it necessarily affect the results. Orne (1962) and Orne and Whitehouse (2000) have identified what they describe as demand characteristics that can be encountered in psychological studies. They found that people, understandably, attempt to make sense of what the experimenter is trying to achieve. So as soon as we ask questions about how people think about something, we are (a) necessarily asking biased questions, and (b) effectively prompting them to answer in a particular way. Demand characteristics, more formally, refer to the totality of cues and role expectations that are inhered within all social contexts, including a study such as this. The consequences or effect of demand characteristics in this situation will vary with the extent to which they are perceived, as well as with the motivation and ability of the person to comply. Demand characteristics are very difficult to control for and, in asking people about the operation of mobile phones, we can recognize that some questions will tend to elicit or prompt a technical answer while other questions will tend to prompt more discursive nontechnical answers. This then is consistent with Norman's (1993) and Clancey's (1997) observations concerning situated cognition. As Norman (1993, p. 4) observes, situated cognition places an emphasis on

> the structures of the world and how they constrain and guide behavior…. Human knowledge and interaction cannot be divorced from the world. To do so is to study a disembodied intelligence, one that is artificial, unreal, and uncharacteristic of actual behavior. What really matters is the situation and the parts that people play. One cannot look at just the situation, or just the environment, or just the person. To do so is to destroy the very phenomenon of interest. After all, it is the mutual accommodation of people and the environment that matters, so to focus upon only aspects in isolation is to destroy the interaction, to eliminate the role of the situation upon cognition and action.

Therefore, we must be aware that all of the responses we received were, in part, a function of the demand characteristics of the study condition; in short, technical questions elicit technical replies and everyday questions elicit everyday answers. Given this, we conclude that the explanations people gave as to how technology works was a function of their ability to adopt the appropriate cognitive style and to manage the situation demanding this cognition. So how people think about interactive technology may be thought of as an interaction between their cognitive propensities and the situation in which their cognition is exercised.

FURTHER WORK

So what are the practical applications of these findings? While it is difficult to imagine how cognitive style might be used to guide the design of, say, custom-made interactive technology (e.g., a mobile phone for above-average empathizers, although its usefulness in marketing is quite clear), it may have consequences for the evaluation of interactive technology.

Evaluation is the cornerstone of HCI; it lies at the heart of the user-centered approach to the development of interactive systems (e.g., the star lifecycle model; Hartson & Hix, 1993). It is the means by which the user experience of the system is fed back to the designer; it is the obverse of design. Many different evaluation techniques are available to the HCI practitioner, but they can be reasonably categorized into four basic themes:

1. Expert evaluation is characterized by the absence of the intended end user of the system but the presence of an expert (e.g., Smith & Mosier, 1986). The expert makes judgments about the design of the interactive technology against a set of guidelines.
2. Model-based evaluation is based on predictions about user behavior made using a psychologically plausible or ergonomic model (e.g., Card et al., 1980; John & Kieras, 1996).
3. Scenario-based, task-based, and cooperative forms of evaluation involve one or more representative users. A typical scenario or task is created with the users working through it, during which problems are identified (e.g., Carey & Rusli, 1995).
4. Finally, there are evaluation techniques that simulate the presence or behavior of a user, such as the cognitive walkthrough (e.g., Poulson, Bovair, & Kieras, 1982; Spencer, 2000).

It is important not to overstate any criticism of these approaches, as they have significantly contributed to the creation of very many usable systems. However all four styles of evaluation treat users like experimental subjects, just as in the classic psychological experiments that (a) sought to make statements about the general population, rather than individuals; and (b) tested hypotheses of the form, interface/artifact A is "better" than interface/artifact B. In all, there typically is no treatment of individual differences beyond a gross categorization, such as novice and expert, or frequent and infrequent users. It may be that this fairly simple systemizer–empathizer–balanced categorization may prove to be both a useful and, just as importantly, a practical means of saying something about individual differences in the experience of end users of a given interactive technology.

ENDNOTES

1. See http://store.irobot.com for more information.
2. Baron-Cohen (2004, pp. 135–136) describes Asperger syndrome (AS) as a variant of autism. He writes, "A child with AS has the same difficulties in social and communication skills and has the same obsessional interests. However, such children not only have normal or high IQ (unlike those with high-functioning autism) but they also start speaking on time.
3. Balanced scores can be so at all three levels of SQ and EQ: high, medium, and low.

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Author's Note

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Human Technology: An Interdisciplinary Journal on Humans in ICT Environments
ISSN 1795-6889
www.humantechnology.jyu.fi

APPENDIX A: THE EQ QUESTIONNAIRE

The Empathy Quotient is intended to measure how easily you pick up on other people's feelings and how strongly you are affected by other people's feelings. Please read each of the 60 following statements very carefully and rate how strongly you agree or disagree with them by circling your answer. There are no right or wrong answers, or trick questions.

1. I can easily tell if someone else wants to enter a conversation.	strongly agree	slightly agree	slightly disagree	strongly disagree
2. I prefer animals to humans.	strongly agree	slightly agree	slightly disagree	strongly disagree
3. I try to keep up with the current trends and fashions.	strongly agree	slightly agree	slightly disagree	strongly disagree
4. I find it difficult to explain to others things that I understand easily, when they don't understand it first time.	strongly agree	slightly agree	slightly disagree	strongly disagree
5. I dream most nights.	strongly agree	slightly agree	slightly disagree	strongly disagree
6. I really enjoy caring for other people.	strongly agree	slightly agree	slightly disagree	strongly disagree
7. I try to solve my own problems rather than discussing them with others.	strongly agree	slightly agree	slightly disagree	strongly disagree
8. I find it hard to know what to do in a social situation.	strongly agree	slightly agree	slightly disagree	strongly disagree
9. I am at my best first thing in the morning.	strongly agree	slightly agree	slightly disagree	strongly disagree
10. People often tell me that I went too far in driving my point home in a discussion.	strongly agree	slightly agree	slightly disagree	strongly disagree
11. It doesn't bother me too much if I am late meeting a friend.	strongly agree	slightly agree	slightly disagree	strongly disagree
12. Friendships and relationships are just too difficult, so I tend not to bother with them.	strongly agree	slightly agree	slightly disagree	strongly disagree
13. I would never break a law, no matter how minor.	strongly agree	slightly agree	slightly disagree	strongly disagree
14. I often find it difficult to judge if something is rude or polite.	strongly agree	slightly agree	slightly disagree	strongly disagree
15. In a conversation, I tend to focus on my own thoughts rather than on what my listener might be thinking.	strongly agree	slightly agree	slightly disagree	strongly disagree
16. I prefer practical jokes to verbal humour.	strongly agree	slightly agree	slightly disagree	strongly disagree

17. I live life for today rather than the future.	strongly agree	slightly agree	slightly disagree	strongly disagree
18. When I was a child, I enjoyed cutting up worms to see what would happen.	strongly agree	slightly agree	slightly disagree	strongly disagree
19. I can pick up quickly if someone says one thing but means another.	strongly agree	slightly agree	slightly disagree	strongly disagree
20. I tend to have very strong opinions about morality.	strongly agree	slightly agree	slightly disagree	strongly disagree
21. It is hard for me to see why some things upset people so much.	strongly agree	slightly agree	slightly disagree	strongly disagree
22. I find it easy to put myself in somebody else's shoes.	strongly agree	slightly agree	slightly disagree	strongly disagree
23. I think that good manners are the most important thing a parent can teach their child.	strongly agree	slightly agree	slightly disagree	strongly disagree
24. I like to do things on the spur of the moment.	strongly agree	slightly agree	slightly disagree	strongly disagree
25. I am good at predicting how someone will feel.	strongly agree	slightly agree	slightly disagree	strongly disagree
26. I am quick to spot when someone in a group is feeling awkward or uncomfortable.	strongly agree	slightly agree	slightly disagree	strongly disagree
27. If I say something that someone else is offended by, I think that that's their problem, not mine.	strongly agree	slightly agree	slightly disagree	strongly disagree
28. If anyone asked me if I liked their haircut, I would reply truthfully, even if I didn't like it.	strongly agree	slightly agree	slightly disagree	strongly disagree
29. I can't always see why someone should have felt offended by a remark.	strongly agree	slightly agree	slightly disagree	strongly disagree
30. People often tell me that I am very unpredictable.	strongly agree	slightly agree	slightly disagree	strongly disagree
31. I enjoy being the centre of attention at any social gathering.	strongly agree	slightly agree	slightly disagree	strongly disagree
32. Seeing people cry doesn't really upset me.	strongly agree	slightly agree	slightly disagree	strongly disagree
33. I enjoy having discussions about politics.	strongly agree	slightly agree	slightly disagree	strongly disagree
34. I am very blunt, which some people take to be rudeness, even though this is unintentional.	strongly agree	slightly agree	slightly disagree	strongly disagree
35. I don’t tend to find social situations confusing.	strongly agree	slightly agree	slightly disagree	strongly disagree

36. Other people tell me I am good at understanding how they are feeling and what they are thinking.	strongly agree	slightly agree	slightly disagree	strongly disagree
37. When I talk to people, I tend to talk about their experiences rather than my own.	strongly agree	slightly agree	slightly disagree	strongly disagree
38. It upsets me to see an animal in pain.	strongly agree	slightly agree	slightly disagree	strongly disagree
39. I am able to make decisions without being influenced by people's feelings.	strongly agree	slightly agree	slightly disagree	strongly disagree
40. I can't relax until I have done everything I had planned to do that day.	strongly agree	slightly agree	slightly disagree	strongly disagree
41. I can easily tell if someone else is interested or bored with what I am saying.	strongly agree	slightly agree	slightly disagree	strongly disagree
42. I get upset if I see people suffering on news programmes.	strongly agree	slightly agree	slightly disagree	strongly disagree
43. Friends usually talk to me about their problems as they say that I am very understanding.	strongly agree	slightly agree	slightly disagree	strongly disagree
44. I can sense if I am intruding, even if the other person doesn't tell me.	strongly agree	slightly agree	slightly disagree	strongly disagree
45. I often start new hobbies but quickly become bored with them and move on to something else.	strongly agree	slightly agree	slightly disagree	strongly disagree
46. People sometimes tell me that I have gone too far with teasing.	strongly agree	slightly agree	slightly disagree	strongly disagree
47. I would be too nervous to go on a big rollercoaster.	strongly agree	slightly agree	slightly disagree	strongly disagree
48. Other people often say that I am insensitive, though I don’t always see why.	strongly agree	slightly agree	slightly disagree	strongly disagree
49. If I see a stranger in a group, I think that it is up to them to make an effort to join in.	strongly agree	slightly agree	slightly disagree	strongly disagree
50. I usually stay emotionally detached when watching a film.	strongly agree	slightly agree	slightly disagree	strongly disagree
51. I like to be very organised in day to day life and often make lists of the chores I have to do.	strongly agree	slightly agree	slightly disagree	strongly disagree
52. I can tune into how someone else feels rapidly and intuitively.	strongly agree	slightly agree	slightly disagree	strongly disagree

53. I don't like to take risks.	strongly agree	slightly agree	slightly disagree	strongly disagree
54. I can easily work out what another person might want to talk about.	strongly agree	slightly agree	slightly disagree	strongly disagree
55. I can tell if someone is masking their true emotion.	strongly agree	slightly agree	slightly disagree	strongly disagree
56. Before making a decision I always weigh up the pros and cons.	strongly agree	slightly agree	slightly disagree	strongly disagree
57. I don't consciously work out the rules of social situations.	strongly agree	slightly agree	slightly disagree	strongly disagree
58. I am good at predicting what someone will do.	strongly agree	slightly agree	slightly disagree	strongly disagree
59. I tend to get emotionally involved with a friend's problems.	strongly agree	slightly agree	slightly disagree	strongly disagree
60. I can usually appreciate the other person's viewpoint, even if I don't agree with it.	strongly agree	slightly agree	slightly disagree	strongly disagree

APPENDIX B: THE SQ QUESTIONNAIRE

The Systemizing Quotient gives a score based on how interested you assess yourself to be in each of the following forms of systemizing. Systemizing is the drive to analyse and explore a system, to extract underlying rules that govern the behaviour of a system; and the drive to construct systems. Please read each of the following 60 statements very carefully and rate how strongly you agree or disagree with them by circling your answer. There are no right or wrong answers, or trick questions.

1. When I listen to a piece of music, I always notice the way it's structured.	strongly agree	slightly agree	slightly disagree	strongly disagree
2. I adhere to common superstitions.	strongly agree	slightly agree	slightly disagree	strongly disagree
3. I often make resolutions, but find it hard to stick to them.	strongly agree	slightly agree	slightly disagree	strongly disagree
4. I prefer to read non-fiction than fiction.	strongly agree	slightly agree	slightly disagree	strongly disagree
5. If I were buying a car, I would want to obtain specific information about its engine capacity.	strongly agree	slightly agree	slightly disagree	strongly disagree
6. When I look at a painting, I do not usually think about the technique involved in making it.	strongly agree	slightly agree	slightly disagree	strongly disagree
7. If there was a problem with the electrical wiring in my home, I'd be able to fix it myself.	strongly agree	slightly agree	slightly disagree	strongly disagree
8. When I have a dream, I find it difficult to remember precise details about the dream the next day.	strongly agree	slightly agree	slightly disagree	strongly disagree
9. When I watch a film, I prefer to be with a group of friends, rather than alone.	strongly agree	slightly agree	slightly disagree	strongly disagree
10. I am interested in learning about different religions.	strongly agree	slightly agree	slightly disagree	strongly disagree
11. I rarely read articles or webpages about new technology.	strongly agree	slightly agree	slightly disagree	strongly disagree
12. I do not enjoy games that involve a high degree of strategy.	strongly agree	slightly agree	slightly disagree	strongly disagree
13. I am fascinated by how machines work.	strongly agree	slightly agree	slightly disagree	strongly disagree
14. I make it a point of listening to the news each morning.	strongly agree	slightly agree	slightly disagree	strongly disagree

15. In maths, I am intrigued by the rules and patterns governing numbers.	strongly agree	slightly agree	slightly disagree	strongly disagree
16. I am bad about keeping in touch with old friends.	strongly agree	slightly agree	slightly disagree	strongly disagree
17. When I am relating a story, I often leave out details and just give the gist of what happened.	strongly agree	slightly agree	slightly disagree	strongly disagree
18. I find it difficult to understand instruction manuals for putting appliances together.	strongly agree	slightly agree	slightly disagree	strongly disagree
19. When I look at an animal, I like to know the precise species it belongs to.	strongly agree	slightly agree	slightly disagree	strongly disagree
20. If I were buying a computer, I would want to know exact details about its hard drive capacity and processor speed.	strongly agree	slightly agree	slightly disagree	strongly disagree
21. I enjoy participating in sport.	strongly agree	slightly agree	slightly disagree	strongly disagree
22. I try to avoid doing household chores if I can.	strongly agree	slightly agree	slightly disagree	strongly disagree
23. When I cook, I do not think about exactly how different methods and ingredients contribute to the final product.	strongly agree	slightly agree	slightly disagree	strongly disagree
24. I find it difficult to read and understand maps.	strongly agree	slightly agree	slightly disagree	strongly disagree
25. If I had a collection (e.g. CDs, coins, stamps), it would be highly organised.	strongly agree	slightly agree	slightly disagree	strongly disagree
26. When I look at a piece of furniture, I do not notice the details of how it was constructed.	strongly agree	slightly agree	slightly disagree	strongly disagree
27. The idea of engaging in "risk-taking" activities appeals to me.	strongly agree	slightly agree	slightly disagree	strongly disagree
28. When I learn about historical events, I do not focus on exact dates.	strongly agree	slightly agree	slightly disagree	strongly disagree
29. When I read the newspaper, I am drawn to tables of information, such as football league scores or stock market indices.	strongly agree	slightly agree	slightly disagree	strongly disagree
30. When I learn a language, I become intrigued by its grammatical rules.	strongly agree	slightly agree	slightly disagree	strongly disagree
31. I find it difficult to learn my way around a new city.	strongly agree	slightly agree	slightly disagree	strongly disagree

32. I do not tend to watch science documentaries on television or read articles about science and nature.	strongly agree	slightly agree	slightly disagree	strongly disagree
33. If I were buying a stereo, I would want to know about its precise technical features.	strongly agree	slightly agree	slightly disagree	strongly disagree
34. I find it easy to grasp exactly how odds work in betting.	strongly agree	slightly agree	slightly disagree	strongly disagree
35. I am not very meticulous when I carry out D.I.Y.	strongly agree	slightly agree	slightly disagree	strongly disagree
36. I find it easy to carry on a conversation with someone I've just met.	strongly agree	slightly agree	slightly disagree	strongly disagree
37. When I look at a building, I am curious about the precise way it was constructed.	strongly agree	slightly agree	slightly disagree	strongly disagree
38. When an election is being held, I am not interested in the results for each constituency.	strongly agree	slightly agree	slightly disagree	strongly disagree
39. When I lend someone money, I expect them to pay me back exactly what they owe me.	strongly agree	slightly agree	slightly disagree	strongly disagree
40. I find it difficult to understand information the bank sends me on different investment and saving systems.	strongly agree	slightly agree	slightly disagree	strongly disagree
41. When travelling by train, I often wonder exactly how the rail networks are coordinated.	strongly agree	slightly agree	slightly disagree	strongly disagree
42. When I buy a new appliance, I do not read the instruction manual very thoroughly.	strongly agree	slightly agree	slightly disagree	strongly disagree
43. If I were buying a camera, I would not look carefully into the quality of the lens.	strongly agree	slightly agree	slightly disagree	strongly disagree
44. When I read something, I always notice whether it is grammatically correct.	strongly agree	slightly agree	slightly disagree	strongly disagree
45. When I hear the weather forecast, I am not very interested in the meteorological patterns.	strongly agree	slightly agree	slightly disagree	strongly disagree
46. I often wonder what it would be like to be someone else.	strongly agree	slightly agree	slightly disagree	strongly disagree
47. I find it difficult to do two things at once.	strongly agree	slightly agree	slightly disagree	strongly disagree
48. When I look at a mountain, I think about how precisely it was formed.	strongly agree	slightly agree	slightly disagree	strongly disagree

49. I can easily visualise how the motorways in my region link up.	strongly agree	slightly agree	slightly disagree	strongly disagree
50. When I'm in a restaurant, I often have a hard time deciding what to order	strongly agree	slightly agree	slightly disagree	strongly disagree
51. When I'm in a plane, I do not think about the aerodynamics	strongly agree	slightly agree	slightly disagree	strongly disagree
52. I often forget the precise details of conversations I've had	strongly agree	slightly agree	slightly disagree	strongly disagree
53. When I am walking in the country, I am curious about how the various kinds of trees differ	strongly agree	slightly agree	slightly disagree	strongly disagree
54. After meeting someone just once or twice, I find it difficult to remember precisely what they look like	strongly agree	slightly agree	slightly disagree	strongly disagree
55. I am interested in knowing the path a river takes from its source to the sea	strongly agree	slightly agree	slightly disagree	strongly disagree
56. I do not read legal documents very carefully	strongly agree	slightly agree	slightly disagree	strongly disagree
57. I am not interested in understanding how wireless communication works	strongly agree	slightly agree	slightly disagree	strongly disagree
58. I am curious about life on other planets	strongly agree	slightly agree	slightly disagree	strongly disagree
59. When I travel, I like to learn specific details about the culture of the place I am visiting	strongly agree	slightly agree	slightly disagree	strongly disagree
60. I do not care to know the names of the plants I see	strongly agree	slightly agree	slightly disagree	strongly disagree

APPENDIX C: THE QUESTIONS ASKED OF THE PARTICIPANTS

What kind of phone do you have and how often do you use it?
What do you use the phone for other than calling?
What happens if you enter the wrong pin number to switch on the phone?
What is in the telephone?
What is in the SIM card?
How is the information used?
Do you know what the PIN code does?
How do you think the telephone works?
Is there a difference between messaging & email?
What happens to the ‘phone during the connection?
Why does the battery go flat when you don't use the phone?
What does the signal availability mean?
What does it mean when the network is busy?
What makes the battery life go down fastest?
What do the bars on the phone mean?