

Toward Making Robots Invisible-In-Use:  
An Exploration Into Invisible-In-Use Tools and Agents

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### Toward Making Robots Invisible-In-Use

One fundamental challenge to human-robot interaction is how to design interactions with these increasingly autonomous agents without overloading people's limits of attention, cognitive load, and patience. This is similar to the challenge posed in human-computer interaction (HCI) with the notion of ubiquitous computing.

#### *The Ubiquitous Computing Perspective*

Ubiquitous computing (ubicom) is often misunderstood as simply being about computers being everywhere. While it may be true that computers are becoming increasingly pervasive in our everyday lives, that is merely the premise, not the thesis, of ubiquitous computing. The most frequently cited description of ubicom is Mark Weiser's *Scientific American* article: "The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it." The goal of making something "disappear" is to quietly empower people. As he put it, "only when things disappear in this way are we freed to use them without thinking and so to focus beyond them to new goals" (Weiser, 1991). This notion extends the definition of computers to include "things that think" (Gershensfeld, 1999; Gold, 2007).

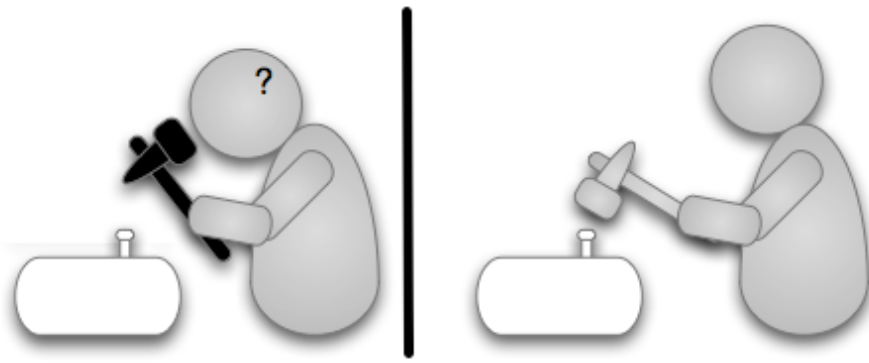
This perspective of ubiquitous computing extends into human-robot interaction issues of making robots so natural, easy, and invisible-in-use, that they fade into the background of everyday

experiences. This contrasts against a model of interacting with robots that demand large amounts of conscious attention directed at the robot in order for the person to get anything done.

### *Invisible-In-Use*

One formulation of this ubiquitous computing perspective is to make tools (e.g., computers and robots) invisible-in-use. Being invisible-in-use means that something is phenomenologically invisible: “the experience of direct interaction with artifacts and tools largely free of conscious monitoring” (Iverson, Heer, & Khooshabeh, 2004).

The idea that tools can become invisible-in-use has been put forth in different forms by prominent philosophers, psychologists, graphic novelists, and others. The philosopher, Heidegger (1992) wrote about the carpenter's hammer becoming ready-at-hand (i.e., invisible-in-use) when he became accustomed to using it, but that the carpenter could easily shift to reflecting upon the hammer as being present-at-hand (e.g., noticing its shape, materials, weight) if desired. See Figure 1.



*Figure 1.* Example of a hammer being present-at-hand (left) and ready-at-hand (right)

Heidegger's concepts of present-at-hand vs. ready-at-hand have influenced much of HCI research, particularly as articulated by Winograd and Flores (1986).

Leder (1990) expanded upon these ideas by referring to the “incorporation” of tools into one’s body; when one masters a skill, the tools that one practices with become incorporated into one’s “corporeal history” (p. 32). At the same time, a breakdown in one’s body (e.g., sickness) can result in the experience of one’s body parts as feeling like heavy weights that require focused attention and will power to move. Normally, one’s bodily performance is tacit.

In the same vein, Michael Polanyi wrote in even more depth about the tacit dimension of human experience (1964): “In an act of tacit knowing we attend from something for attending to something else; namely from the first term to the second term of the tacit relation” (p. 10). He uses the example of someone learning to use a probe,

shifting from experiencing the impact of the probe against his hand to automatically sensing the meaning of feeling impacts from the tip of the probe.

Phenomenological philosopher Merleau-Ponty (1962) expressed this phenomenon in terms of a person's sense of "I can," which is shaped by the tools that the person has mastered; when a person has mastered a tool, she or he has a "maximum grasp" (Dreyfus, 1972) of it (that is goal and context specific). Merleau-Ponty provided the example of a blind man using a walking stick: "the stick is no longer an object perceived by the blind man, but an instrument with which he perceives. It is a bodily auxiliary, an extension of the bodily synthesis" (Merleau-Ponty, 1962, p. 152).

Ecological psychologist, James Gibson (Reed & Jones, 1982) conceptualized an entitive vs. functional point of view. He presents the notion of a field of possible actions such as those afforded by the expert use of a car: "Within the boundaries of the road lies, according to our hypothesis, an indefinitely bounded field which we will name the field of safe travel. It consists, at any given moment, of the field of possible paths which the car may take unimpeded. Phenomenally it is a sort of tongue protruding forward along the road" (p. 120). Faster sports cars might have longer tongues than slower ones. Dant further delved into this particular example as a driver-car experience (2004).

Psychologist Mihaly Csikszentmihaly (1991) similarly wrote about the state of "flow," which is characterized as a state of complete

absorption or concentration upon an activity (e.g., being in “the zone”). He provides examples of athletes, musicians, programmers, etc. reaching the state of flow when being totally immersed in their given activity in a way that feels positively energized, rather than overwhelming or negative. While the experience of flow is highly subjective, varies from person to person, and varies from situation to situation, a wide range of people recognize it as a common experience.

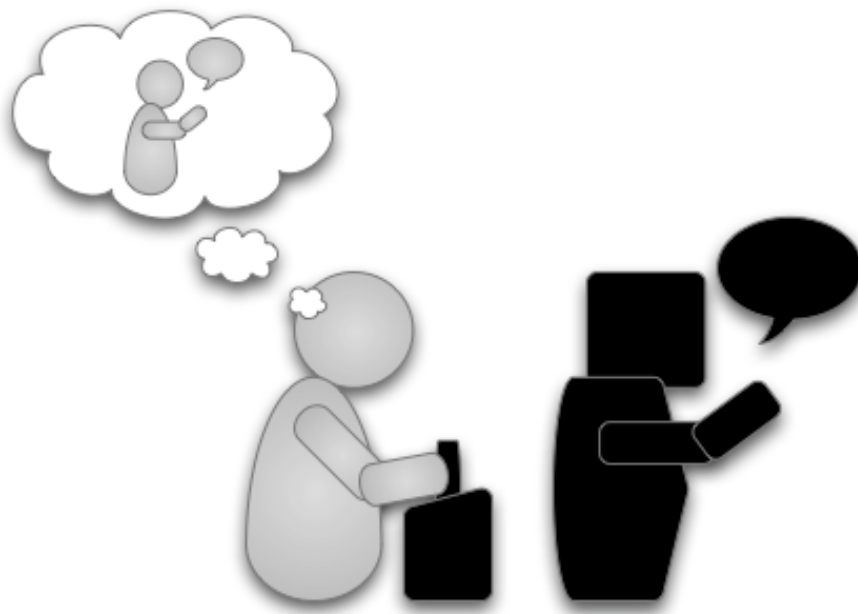
Graphic novelist Scott McCloud (1993) provides many other vivid examples of people fusing with their cars, telephones, forks and knives, and hats—a starting set of previously lacking empirical examples from this literature and idea.

These related concepts have their own nuances, but all broadly speak to the same first-person experience of a tool becoming invisible-in-use. It is this phenomenon that we explored in the current studies, eliciting personal experiences and stories to gain insights into our understanding of what it would mean for tools and animals to become invisible-in-use and how robots and other tools might become invisible-in-use, too.

### *Robots as Invisible-In-Use*

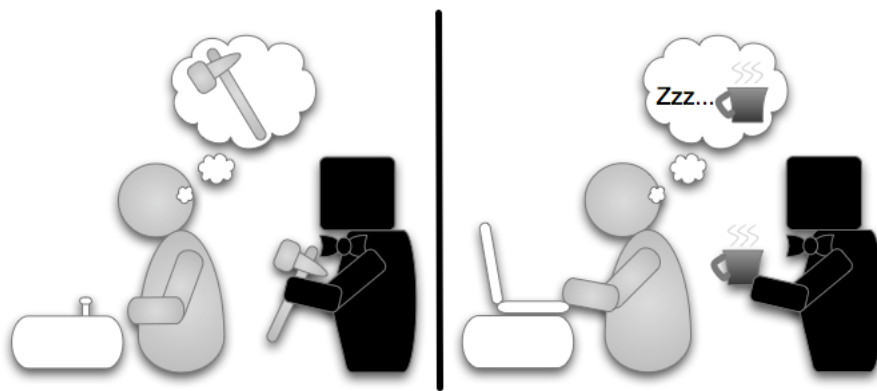
As explicated in prior work (Takayama, 2009), there is an important difference between how people’s in-the-moment vs. people’s reflective perceptions and actions. In-the-moment perspectives are spontaneous and might be described as, “At the time,

it seemed as if...” Reflective perspectives are more calmly distanced and thoughtfully formulated than in-the-moment perspectives. As with computer social actors (Nass & Moon, 2000; Reeves & Nass, 1996), there can be a disconnect between how robots seem in-the-moment vs. reflectively. Robots can become invisible-in-use when they fade into the background of one's experience in-the-moment even though one objectively knows that the robot is not a part of oneself upon further reflection. This is the ultimate immersive telepresence experience, as depicted in Figure 2.



*Figure 2.* Robots can become invisible-in-use as a medium through which a teleoperator is acting

Similarly, more autonomous robots can provide services to help people in ways that are unobtrusive and do not rely upon explicit commands from the user. As an example, a person working on task (e.g., trying to hammer a nail or stay awake long enough to complete a homework assignment) might be helped by robots in ways depicted in Figure 3.



*Figure 3.* Robots can become invisible-in-use by unobtrusively providing services to people

Although the spirit of ubiquitous computing ran against the idea of using interface agents (1992), Weiser got stuck on the point that one type of invisible agent might be butlers. This may not necessarily correspond to the real world service that butlers provide, but it indicates an inclination toward providing services to people in unobtrusive and more implicit (Ju & Leifer, 2008) way, e.g., ubiquitous robots (Kim, Kim, & Lee, 2004) and butler-like agents (Sohn, Ballagas, & Takayama, 2009).



Robots are commonly imagined as either being “just tools” or as being fully autonomous systems that interact with people in much the same way that people interact with each other; however, there are many ways to interact with and through robots that are not addressed by those models of HRI. These two canonical stances ignore how people actually come to interact in-the-moment with robots, behaving in ways that do not necessarily align with their reflective beliefs about the robots. The goal of the current studies was to gain insights into the ways that robots might become invisible-in-use, regardless of whether they are “just tools” (as in the first study) or they are non-human agents (as in the second study).

In the following sections, we present two empirical studies of how tools and agents become invisible-in-use and visible again. First, we present an interview and a survey about people’s experiences with tools that have become invisible-in-use in their own lives. Second, we present an interview study about equestrian’s experiences with riding horses, addressing issues of how animal agents that can work with and against people. Finally, we discuss the results in light of their implications for theory and design in human-robot interactions.

### **Tools Study**

By studying how tools become invisible-in-use, we aimed to gain insights into how robots and other computational system might also become invisible-in-use.

### *Respondents and Interviewees*

Respondents for the survey ( $N=46$ ) and participants for the interviews ( $N=19$ ) were recruited through campus announcements. All participants were students at Stanford University, over 18 years of age, who granted informed consent to participate in the study, and were paid in course study participation credit in Communication and Computer Science courses.

### *Hypotheses*

Based upon the idea that breakdowns are key to understanding how tools become present-at-hand (Winograd & Flores, 1986), we hypothesized that (H1) breakdowns would make invisible-in-use tools visible again. Because we associated the ideals of ubiquitous computing with the ease of use, we also hypothesized that (H2) tools that are easy to learn and comfortable to use would become invisible-in-use.

### *Tools Study Methods*

#### *Surveys*

The survey was administered online with this set of open-ended (i.e., free response, not closed-ended) questions: Please take a moment to think about a tool that you have used that became invisible-in-use.

1. Please describe the tool that became invisible-in-use to you.
2. For what activities do (or did) you use the tool?

3. How did you learn to use the tool? How did it become invisible-in-use?
4. Why did the tool become so invisible? Was there something about the properties of the tool itself, the context in which you learned to use it, or were some other factors involved?
5. Approximately how long did it take for the tool to become invisible-in-use for you?
6. Please write about a time (or times) when a tool broke down or otherwise required you attention.
7. In general, what makes a tool visible (i.e., brought to the center of your attention)?
8. Are there any other thoughts you would like to share about the tool or about this concept of invisible tools?

Upon completion of the survey, respondents were debriefed.

### *Interviews*

The interviews were conducted in person and consisted of the following set of open-ended questions:

1. Some people believe that tools can become a part of one's self when using them. Please tell me about a tool that became a part of you at some point in time.
2. Please tell me about a tool that you have completely mastered.
3. Please tell me about a tool that you feel completely comfortable using.

4. Please tell me about a tool that you have sometimes felt is actually a part of yourself.
5. Please tell me about a tool that became so familiar to you that it became invisible-in-use.

For each tool mentioned, we asked:

1. How did you learn to use the tool?
2. How did it become so familiar?
3. Why do you think the tool became so invisible?
4. How long did it take to become invisible-in-use?

Finally, we asked:

1. Please tell me about a time when a tool became visible again.
2. Please tell me about a time when an invisible tool broke down.
3. What do you see as the difference between invisible and visible tools?
4. What is your definition of a tool?

With permission, interview responses were audio recorded and transcribed. Upon completion of the interview, participants were debriefed.

In collecting data for this study, we were cautious to refrain from judging people's responses and made every effort possible to make respondents feel comfortable and confident in their answers. We were careful to ask questions in terms of their own first-person perspectives

(Varela & Shear, 1999) and emphasized that they could use their own definitions of tools and invisible-in-use tools, tell us about tools that they felt reflected the concept of the invisible-in-use tools, and discuss personal experiences with particular tools rather than tools in general. During the interviews, if a participant asked if the tool had to be literally invisible (i.e., not seen), we answered that it did not necessarily have to be literally invisible. If a participant was confused about the meaning of invisible-in-use, we repeated the examples of the blind man's cane or the carpenter's hammer.

#### *Data Analysis*

The main phases of empirical phenomenological research data analysis (Giorgi, 1985) that we used are: (1) data constitution, (2) transforming raw data into phenomenological descriptions, (3) psychological reflection on each example to yield structure of each example, and (4) identifying general psychological structure from examples (p. 161).

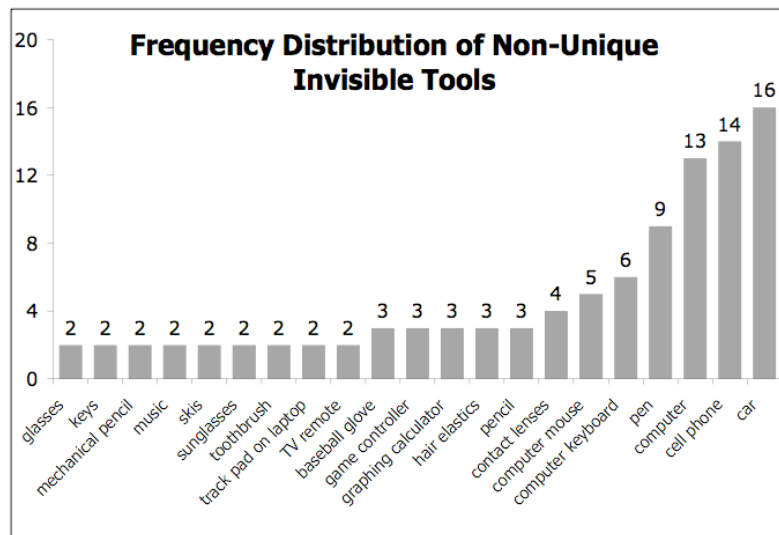
In transforming the raw data into phenomenological descriptions, we analyzed each invisible tool example down to the essence of what made the tool invisible-in-use to the respondent, how it became invisible-in-use, and what (if anything) it was about the tool itself that the respondent believed made it invisible-in-use. In searching for structures for each example, we reviewed the responses and their distilled forms to identify themes and structural patterns that cut across

examples. We present general psychological structures from the examples in the following section.

### *Results and Discussion*

#### *Types of Invisible-in-Use Tools*

Out of the 132 invisible tools reported by respondents and interviewees, 33 of them were unique (i.e., they were only mentioned once). The 33 unique items included: ballet shoes, braces, chopsticks, credit card, ice skates, light switches, pool cue, saxophone, staplers, swimming goggles, tennis racket, tweezers, wrist watch, and yoga mat. Those items that were reported by more than one respondent are presented in Figure 4.



*Figure 4.* Frequency distribution of invisible tools reported (items mentioned more than once)

Cars, cell phones, computers, and pens were the most frequently mentioned items. Out of the 132 invisible tools reported, 51 of them involved a computer in some way (e.g., computer, computer keyboard, computer mouse, graphing calculator, cell phone), 55 of them were purely mechanical (e.g., baseball glove, keys, mechanical pencil, pen, skis, toothbrush), and 38 of them involved items worn on one's body (e.g., cell phone, contact lenses, hair elastic ties, hat, shoes, sunglasses, wallet, watch).

#### *What Makes Tools Invisible-in-Use*

Several themes emerged from the descriptions of their psychological experiences of having tools become invisible-in-use.

The strongest themes included:

*Reliability.* Being able to rely upon the performance of a tool is absolutely key to tools becoming invisible-in-use. When invisible tools disappointed users, it was often because of unreliable behavior, disrupting their everyday routines (e.g., computers failing, contact lens drying out). Exemplar statements included: “If you're wearing high heels and you have to run, you don't feel confident. Even if you're not wobbly... the heel isn't really supporting you so you have to run on your toes,” and, “as soon as it breaks, my whole routine totally falls apart and... everything becomes prioritized behind replacing the cell phone, making the cell phone work again, charging the cell phone, going to the... store and yelling.”

*Predictability and consistency.* Being able to predict what the tool would do was also very important for almost all invisible-in-use tools. When expectations were not met or people were surprised by the behavior of the tool, that made the tool visible (i.e., present-at-hand). Exemplar statements included: “The [computer] keys always followed the same layout, even across platforms and different keyboard versions.” Once the user knows what to expect from using the tool, the tool can become invisible-in-use.

*Familiarity.* Most examples of these invisible tools were objects that the person had owned for many years and used very often (e.g., hair elastics, cell phones, hats). Some tools were only invisible-in-use if it was the person's own tool (e.g., 4-year old cell phone), whereas others



could quickly adapt to using many instances of the tool (e.g., pen).

Exemplar statements included: “over time, the positions of the keys became more familiar... With more practice, my fingers eventually remembered the exact locations of the keys,” and, “[your own car is] a familiar environment and everything is just the same. You just feel like you're at home. I don't have that feeling when I get into other cars.”

Rental cars feel less invisible-in-use than one's own car at home.

*Sense of control.* Having a sense of control over the tool as opposed to feeling out of control with the tool (e.g., driving a car) was also critical to a tool becoming invisible-in-use. Exemplar statements included: “I honestly miss the ease and complete control with which I maneuvered my old [cell] phone.”

Contrary to our original hypothesis (H2), we learned that several aspects we expected to be important for tools to become invisible-in-use were not actually required.

*Comfort.* Although comfort was often mentioned as one aspect of people's invisible tools, it was not always necessary. Ballet shoes and figure skates are not comfortable and take a very long time to break in, but these were mentioned as being quite invisible-in-use to some respondents. Comfort can help to speed up the time until one reaches a point of the tool becoming invisible-in-use (e.g., estimated a few days for new running shoes to become invisible-in-use), but comfort is not required for a tool to become invisible-in-use.

*Ease of learning.* The ease of learning how to use a tool was sometimes cited as the reason why a tool became invisible-in-use, but this aspect of tools was not necessary either. Graphing calculators, TV remotes, and computers are not necessarily easy to learn how to use, but these persistent users were able to reach a point of feeling that such complex tools are invisible-in-use. As with comfort, easy to learn tools seem to become invisible-in-use more quickly (e.g., stapling, swiping a credit card), but ease of learning was not absolutely necessary.

*Design.* Thoughtful product design was often cited as why some tools became invisible-in-use (e.g., Mac operating systems, video game controllers), but this was not absolutely necessary (e.g., poorly designed toothbrushes, unusual mechanical pencils). Even though some toothbrushes and mechanical pencils can be quite awkward to adapt to, even these types of tools were reported as becoming invisible-in-use.

While these are certainly not the only aspects of these tools that made them invisible-in-use to our respondents, these were the primary themes that cut across their experiences.

*Qualia: What it is Like*

Because a tool becoming invisible-in-use is a very personal, first-person experience (Varela & Shear, 1999), we aimed to gain a sense of the qualia (i.e., what it is like) for a person to experience a tool that is invisible-in-use. While it might be fundamentally impossible to fully understand the qualia experienced by others (Nagel, 1974), we noticed that respondents consistently used these phrases to describe their experiences with these tools:

- Don't need to think about it
- Effortless
- Extension of me
- Forget you're using it
- Instinctual
- Natural extension
- No longer think of them as new or technology
- Part of me
- Second nature
- Take for granted and don't miss until it's gone
- Use it without even noticing
- Very fluid motion

Using more specific examples, touch typing on computer keyboards and driving cars were experiences that several respondents described to us. They talked about both experiences in terms of the tool being an extension of one's sense of self: "The keyboard had become an extension of myself. There was no more thought required for the input of text." Similarly, in the driving example, one respondent said, "Usually, you are very aware of driving, but there are definitely times when I'm completely unaware and all I'm focused on is the road so it's like the car is an extension of me."

On the other hand, other respondents talked about the same tools as projections of their desired outcomes. Regarding the keyboard, one respondent reported, "When I'm typing notes, those are the thoughts that are going through my head that are just on there. It's kind of like a projection of what's in my head." Regarding driving, another respondent said, "Obviously, I'm in a car and it's not invisible in the sense physically but it's invisible in the sense mentally. I don't think about it anymore. It's a natural projection."

Some responses focused upon the fusion of the tool with one's self: "When you're skiing or you become decent at it, then there's a kind of synergy that happens between your legs, your boots, and your skis. It just becomes one system for getting around the mountain and then the tool becomes an extension of you, as you have a different organ that allows you (like how fish have gills that you can get around

underwater) skis are sort of an organ that you can use... to get around mountains.”

Altogether, these descriptions of what it is like to experience a tool as being invisible-in-use provide a grounding for evaluating how much a computational system such a robot is experienced as being invisible-in-use, too.

#### *How Tools Become Invisible-in-Use*

While each tool had its own story about how it became invisible-in-use, a few themes emerged from reviewing the responses.

*Active practice.* Active practice was the most often described way that people said their tools became invisible-in-use. Sometimes this practice was a part of formal training (e.g., driver's education or writing with pencils/pens) and sometimes not (e.g., using a cell phone or chopsticks). This process requires repetition over long periods of time, which is demanding of the user, but many respondents engaged in prolonged practice because they saw using the tool as a necessity (e.g., commuting to school, learning writing/literacy). Practiced routines (e.g., brushing teeth or hair) and social norms (e.g., wearing makeup, text messaging on cell phones) were other unanticipated reasons we learned about that motivated people to persevere and practice with their tools.

*Passive exposure, observation, and use.* Passive exposure, observation, and use was another way that people's tools became invisible-in-use.

Contact lenses were described by several respondents as being something they just got used to; wearing the lenses throughout the day was something that just took time to get used to. Although many respondents were unable to recall how they learned to use more everyday tools (e.g., light switch, toothbrush, hair dryer), most speculated that they learned from watching their parents routinely use those tools.

*Trial and error.* Trial and error was a common response, as well. Tools such as the TV remote control, tweezers, computers, and cell phones were described in this way. No one formally taught them how to use the tool and they did not read any manual or watch a tutorial about how to make use of the tool.

What is most notable about these findings is that the most prevalent way that these tools became invisible-in-use to our respondents was simple practice through actual use. Several respondents described learning through watching other people using the tool and imitating them; this is consistent with learning theories of communities of practice (Lave & Wenger, 1991). By engaging in a process of legitimate peripheral participation, people master their tools.

#### *How Tools Become Visible*

In analyzing the ways that people reported their tools becoming visible again, we were surprised to find that tools becoming visible

again had to do with much more than just breakdowns (H1). Among the many ways that tools became visible to respondents were:

- Requiring conscious attention: A tool is new (e.g., new car) or breaks down (e.g., flat tire)
- Being annoying: A tool's presence and/or use is irritating (e.g., feeling dried contact lenses in one's eyes)
- Being absent: This is consistent with the idea that invisible tools are taken for granted and yet indispensable (e.g., forgetting one's cell phone at home)
- Forgetting how to use it: Losing one's skills in using the tools (e.g., forgetting how to play the saxophone)
- Considering alternatives: When alternative tools become available, one's existing tools can become more visible (e.g., waiting for a laptop to compile large amounts of code because it has less RAM than most computers on the market)
- Transferring knowledge to different forms of the tool: When an instantiation of a tool is too different from one's own, the new one becomes quite visible (e.g., shifting from computer mouse to track pad)
- Anticipating urgency: When a tool absolutely must work reliably (e.g., waiting for mobile phone call from sick mother) or when a tool is known to fail catastrophically (e.g., driving in a car that has problems)

Contrary to our original hypothesis (H1), it is not simply the breakdown of a tool that makes it visible. Simply the threat of a tool breaking down can make a once invisible-in-use tool come to the forefront of one's conscious attention. One respondent described this situation while on a road trip across the country: “It became very visible because I was very nervous. I didn't want the car to break down in the middle of nowhere so I'd keep looking at the dials, the meters, keep everything low. Once I did that, it would work, but of course it was no longer invisible.” This is consistent with the earlier finding that a tool must be reliable to become invisible-in-use.

While the findings from this tools study identified ways that mostly inanimate tools become invisible-in-use, we were also interested in hearing more about how agents (e.g., animals) can also become invisible-in-use. Although an animal has its own agency, it is also possible for companion species such as dogs (Haraway, 2003) to be used for human pursuits (e.g., chasing, herding, hunting) in such a way that they become invisible-in-use from the human's perspective. As such, the following study consisted of an inquiry with expert equestrians.

### **Animals Study**

As in the realm of human joint activities such as ballroom dancing (Clark, 1996), humans and non-human agents can also engage in such a way that it feels like two agents are acting together as one. A



canonical example of this is how equestrians and their horses ride together. Indeed, horses are autonomous agents, which makes them somewhat more comparable to autonomous and semi-autonomous robots than inanimate tools. Because the first study on invisible-in-use tools did not touch upon non-human agents like animals, this subsequent study focused upon non-human agents that might provide useful insights for interacting with increasingly autonomous systems such as cars. Thus, the research question in this study was: What can we learn from equestrians about how to interact with autonomous agents as though they are invisible-in-use?

#### *Respondents and Interviewees*

Because expert equestrians are more difficult to locate and recruit, the sample size of this study was smaller than the previous study; there are fewer expert equestrians than everyday people. We interviewed one expert equestrians with over 40 years of experience with horses. We also surveyed five expert equestrians, who had been riding horses since they were young children. All respondents were over 18 years of age, residing in the United States; they granted informed consent to participate in the study and were given gift certificates as thanks for their time and effort.

The survey respondents each had much more than ten years of experience with riding horses; they had started riding when they were 4, 5, 8, 9, and 12 years of age. Several of them owned their own horses

or grew up in families who owned horses. Some of them rode horses every day while others rode horses several times per week. Two of them rode competitively at the national level and four of them used to ride in shows.

The interviewee, RQ, grew up on a ranch with cattle and horses for 42 years. He also apprenticed with other equestrians in California for several years before returning to his ranch in Montana.

### *Animals Study Methods*

#### *Survey and Interview Questions*

A survey was administered via email with this set of open-ended questions:

1. Could you say a bit about your personal experience with horses (i.e., number of years, types of experiences)?
  - How would you describe your relationship with your horse(s)?
  - From your personal perspective, what is it like to ride with your horse(s)?
2. Have you ever experienced a time when it felt like you and your horse were truly acting as a single unit? If so, could you please describe that event and experience?
  - How frequently does this happen?
  - If this has happened more than once, could you please describe another time when this happened?

3. In what ways does your horse exert its own agency? In other words, how does your horse assert independence and autonomy when you are interacting with it?
  - How frequently does this happen?
4. Could you describe a specific event in which your horse exerted its own agency?
  - When/is it appropriate for your horse to exert its own agency?
5. Regarding communicating with your horse(s):
  - In what ways do you most effectively communicate with your horse(s)? Could you describe specific instances of this?
  - What are the least effective ways of communicating with your horse(s)? Could you describe specific instances of this?
6. Have there ever been breakdowns in your coordination/communication with your horse(s)? If so, could you please say a bit about what happened?

### *Data Analysis*

The same empirical phenomenological research methods used in the previous study (Giorgi, 1985) were employed in the current study.

### *Results & Discussion*

#### *What Makes Horses Invisible-in-Use*

Although we did not introduce the concept of horses being invisible-in-use to the respondents in this study, we talked about the equestrian and horse were acting as a single unit. Almost all of the

respondents immediately understood what we meant by this and related their own personal stories about when they experienced it.

*Harmony.* The notion of feeling in harmony was critical to reaching that level of joint activity. Respondents talked about being in harmony, in sync, and “in the zone” with the horse. When the rider and horse are not in harmony, they are not able to act as one: “There can be days where you and the horse have different agendas and everything can feel a little off.” More of this will be explained in the section on Qualia.

*Effective Communication.* Rather than simply using a tool, riding a horse was more often described as extremely effective communication between the equestrian and horse. As one respondent wrote, “I would describe it more like [the horse] knew exactly what I was asking and was very quick and happy to respond.” Having an implicit understanding and trust of what the equestrian is asking for is important for the rider-horse relationship. Not only must the horse understand what the rider is trying to do, but the horse must also trust that the rider will not put them in danger. As RQ put it, “They have to believe that you can get the job done... You can put them in stressful situations, and they’ll be confident in your ability to keep things OK. You can jump ‘em off a bank into water when they’re confident in you. When you ask, they believe in you so they go.”

He describes his communication with his horses as being about feeling and anticipating: “What we’d like is the horse to feel us right down to the center of us... When I’m on my horse, I get ready to go, and he goes. He feels that so he just goes. When I’m ready to quit, I don’t have to saw on the reigns... When you’re sitting on an animal, they can feel that.” RQ did not talk about how to pull on the reigns, kick, or give particular signals; he trains with his horses until they can communicate at the level of intentions, not just forward, backward, left, right, faster, slower.

*Practice.* As in the first study, we found that practice seems to help. As one equestrian wrote, “The more time I spend with them and ride them, the better we get along and our moods do not clash.” However, RQ noted that “to get [horses] to trust and believe in you isn’t something that has to be a long-term deal... When you work with the horse, you have to come across as confident, not arrogant or cocky.” Practicing and forming a trusting relationship with the horse enables the rider and horse to act as a single unit.

*Relationship on the ground.* One surprising element that did not matter was one’s “on the ground” relationship with the horse. One respondent reported, “I think that if you ride a horse, your relationship with the horse on the ground is pretty irrelevant.” RQ also stated that “some people think that if they love their horse enough, it will be fine. That doesn’t cut it. Loving your horse doesn’t help enough unless you’re

actually fixing problems; you need to be the one that he can lean on.”

Another respondent reported that, “I don’t know if they equate the person who gives them treats with the person who is on their back.”

These descriptions relate to the notions of tools being present-at-hand (e.g., reflecting upon the horse standing there in front of you) vs. ready-at-hand (e.g., riding with the horse in-the-moment) as being very different perspectives.

*Qualia: What it is Like*

One respondent wrote, “I felt like my mare and I were acting as a single unit today. We were doing some light jumping and it seemed as though she knew what I wanted her to do, even before I asked her. She hasn't been jumped in a while, but we really listened to each other and had a fabulous ride.” Another shared, “This happens mostly when I am relaxed and not thinking about specifically how the horse is going but when I'm focused on accomplishing a goal, like trying to jump a series of fences.” These answers resonate with other descriptions of this experience being “Zen-like,” feeling “in harmony” with the horse, feeling “like a team,” and being “in the zone.”

While these are somewhat similar to descriptions seen in the first study, these descriptions are oriented toward there being another agent to sync and communicating very effectively with rather than toward there being some tool to master.

*How Horses Exert Agency*

One respondent said that she had never felt like she and the horse ever acted as a single unit. She responded, “I always felt that riding was more of a communication between two different beings.” She explained that the horses she rides exert their independence on a regular basis: “The two horses that I rode most often definitely asserted independence. I could tell this because they would usually do what I asked, but it always felt like I would ask and they would agree to do it. It would be like they had a choice.” This is consistent with the idea that one is communicating with the horse with more or less effectiveness.

Horses also communicate with people to exert their own agency. “They are big and strong so they usually resist things they don’t like by using that to their advantage. Like running away in the paddock if they don’t want to be caught, putting their head in the air if they don’t want the bridle on, bucking and balking if they don’t want to go somewhere in the ring. That type of stuff. [It] can be dangerous, but usually they are just trying to send a message and register their dislike, not actually hurt you.” Even if horses are not using spoken language, they clearly use bodily language to express likes and dislikes.

There were times when the respondents felt that it was appropriate for the horses to exert their own agency. For example, when finding footing approaching a jump or obstacle, it makes more sense for the horse to decide exactly where to step. Another respondent answered that “I would say it is appropriate for them to take over when

they are in pain... Also, if the rider is making unjust mistakes, it may be appropriate for a horse to ignore them.” This calls for the horse to make an independent judgment about the appropriateness of the rider’s requests, an issue that directly corresponds to the need for trust between the equestrian and horse.

### **Implications for Theory**

While there are many philosophical theories about the concept of tools become ready-at-hand, proximal, functional, and phenomenologically invisible-in-use, there is limited empirical data to ground this concept and to extrapolate and predict what tools more readily afford becoming invisible-in-use and how they do so. That is the gap that these studies aim to begin to fill.

From this gathering of personal stories, we have gleaned at least a few lessons that implicate theories surrounding tools becoming invisible-in-use.

- Types of invisible-in-use tools and agents: While most examples provided by philosophers consist of purely mechanical tools (e.g., blind man's walking stick, carpenter's hammer), the notion of invisible-in-use tools and agents extends to include computational tools (e.g., computers, cell phones) and autonomous agents (e.g., horses).
- Perspective upon the tool: A given tool can go in and out of one's awareness over very short periods of time, mostly depending upon



when where one is attending. It is not an inherent property of the tool.

- **Becoming invisible-in-use:** Tools become invisible-in-use in ways that extend beyond only physical and psychological means; they also become invisible-in-use through social pressures and norms (e.g., cell phone adoption).
- **Becoming visible again:** Tools that were once invisible-in-use can quickly become visible again through many means, not limited to breaking down.

These studies present a step toward fleshing out the concept of being invisible-in-use. By drawing from the first-person experiences of people who are not already steeped in concerns of making computers or robots invisible-in-use, we have drawn from the essences of their experiences to more thoroughly understand the experience of a tool or animal becoming invisible-in-use.

### **Implications for HRI Design**

Many of the lessons learned from this set of inquiries can be applied to the design of computational tools, including robots, to become invisible-in-use.

Learning how to use a tool so that it can become invisible-in-use can take a long time (on the scale of years, not just hours or days). That is not unreasonable if the tool is worth using and/or if there is enough

motivation for the person to continue to learn to use the tool over long periods of time (e.g., driving cars, touch typing).

While comfort, ease of learning, and design can improve the user experience of a tool, none are necessarily required for a tool to become invisible-in-use.

There are many ways that the current findings align with definitions of “intuitive” user interfaces as defined by Naumann, et al. (2007): “A technical system is, in the context of a certain task, intuitively usable while the particular user is able to interact effectively, not consciously using previous knowledge.” Of particular relevance to being invisible-in-use, these authors focus upon the application and non-conscious use of previous knowledge, leveraging existing intuitive understandings of sensorimotor (and higher levels of) knowledge to make interfaces less cognitively demanding to use in context.

Any given tool can shift from moment to moment between being invisible-in-use and visible again. Therefore, it is important to design for both orientations toward robots, ideally enabling the user to effectively use and interact with the robot to achieve one's goals while remaining invisible-in-use (through practice, routine use, minimal attentional requirements, etc.) and to effectively deal with the robot when visible again (e.g., support the user in coping with breakdowns, annoyances, absences, memory lapses, etc.). When breakdowns occur or when people need an explicit understanding of what the agentic

robot is doing, accountability (Button & Dourish, 1996) is particularly useful; by providing a sense of the structure and functions of what is going on below the surface of agentic robots' actions. This is also discussed in the ubiquitous computing literature as seamful design (Chalmers & Galani, 2004) as opposed to the fully invisible-in-use approach to interaction design.

It is not always good to be invisible-in-use. Speed dial features of cell phones and the mindless swiping of credit cards are not necessarily desirable because these tools can make the user rusty in his or her ability to use other phones to make phone calls and to not fully realize just how much money one is spending.

If it is desirable for a computer or robot to become invisible-in-use, then some guidelines to take away from the current study include:

- Reliability is critical to becoming invisible-in-use.
- Design robots to behave predictably and/or consistently across instantiations.
- Enable the user to feel completely in control of the tool. Taking steps toward providing the user with a sense of self-efficacy (Bandura, 1997) can be used to achieve this goal.
- Do not design an interaction to require constant or frequent conscious attention.
- Encourage practice with the tool so that the user can become familiar with the tool through use.

- Enable extremely effective communication between people and increasingly autonomous robots.

While this is not an exhaustive list of lessons to be learned from tools and animals that become invisible-in-use, it is a starting point from which to build and refine our understandings of what it is like for a tool to fade into the background of experience.

Similarly, the findings from the equestrians study can inform the design of shared control systems that use both human and robotic autonomy. Ideally, these interaction designs can and will come to feel like the human and robotic systems are acting as one. There will inevitably be a need for fluid, implicit, and reliable communication between people and robots in such situations. There are many open questions regarding which agent should override the other when it comes to making final decisions. Should an auto-pilot override a human pilot in an airplane if the pilot is making “unjust mistakes?” How would the system know that the human pilot is making mistakes? Automatic braking systems in cars already take control over how the brake is pumped when a human driver slams on the brakes, yet human drivers still feel like they are in control of the car. These studies provide grounded examples of human-nonhuman interactions from which it becomes possible to pose broader questions about interactions between people and increasingly autonomous robotic systems.

## **Future Work**

There is clearly room for further work in this research and design space, especially in more specific types of robots (e.g., humanoid robots), particular task domains (e.g., cleaning), and particular user groups (e.g., people from different demographic categories).

The current studies were purposefully designed to be open-ended, not limited to the domain of robots, but more focused explorations into this domain could narrow the scope of inquiry to particular robots or types of robots. For example, researchers in HRI are been exploring how to use nonverbal behaviours inspired by human-dog interactions to design more readily readable affective communications (Syrdal, Koay, Gacsi, Walters, & Dautenhahn, 2010). Similarly, we can draw from lessons learned by equestrians to inform the design of human interaction with increasingly autonomous motor vehicles; indeed, motorcycles are often called “iron horses.” In terms of designing agentic robotics to be more invisible-in-use, we can see ongoing research and user-centered design in HRI that enables brief moments of interaction (e.g., 6 seconds) between longer periods of parallel work between the people and robots in the environment (e.g., Hütenrauch, Green, Norman, Oestreicher, & Eklundh, 2004).

Drawing the connections between such invisible-in-use tools and acceptance/adoption of the technologies could be further explored through models such as the Unified Theory of Acceptance and Use of

Technology (Venkatesh, Morris, Davis, & Davis, 2003), particularly in terms of effort and performance expectancies.

### **Conclusions**

This review of the theoretical background of tools becoming invisible-in-use and empirical studies of examples of such experiences provides the groundwork from which we can begin to understand how it is that people come to incorporate tools into their first-person skills and experiences. It also provides the HRI research and design community with guidance for how to enable robots to fade into the fabric of everyday life instead of being attention-demanding agents, taking a step toward exploring how to reach the goal of empowering people through robots that are more invisible-in-use.

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