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The Design of Implicit Interactions

or, Making Interactive Objects Less Obnoxious

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Introduction

Imagine, for a second, a doorman that behaves as automatic doors do. He does not acknowledge you when you pass by, or approach. He gives no hint which door can or will open—until you wander within 10 feet of the door, whereupon he flings the door wide open. If you arrived after hours, you might stand in front of the doors for awhile before you understood that the doors are locked, because the doorman's blank stare gives no clue.

If you met such a doorman, you might suspect psychosis. And yet this behavior is typical of our day-to-day interactions not only with automatic doors, but any number of interactive devices. Our cell phones ring loudly even though we are clearly in a movie theatre. Our alarm clocks forget to go off if we do not set them to, even if we've been getting up at the same time for years. Our computers interrupt presentations to let everyone know that a software update is available. These problematic interactions are often attributed to the lack of "intelligence" on the part of misbehaving devices—but are actually symptoms of our as-yet lack of social sophistication in designing *implicit interactions*.

Implicit interactions represent an important research frontier in interaction design. Whereas traditional interaction design has focused on *explicit interactions*, where people's use of computers and the like rely on explicit input and output, implicit interactions occur without the explicit behest or awareness of the user. Such interactions are employed when the user is focused on something other than trying to get an interactive device to do what they want, perhaps because the user is physically, socially or cognitively engaged, or because he or she is not cognizant of what direction the interaction should go.

It is not our intent to champion implicit interactions as being superior to explicit interactions, but to make them requisite to any interaction designer's repertoire, ready at hand when situations arise. This article outlines the emerging area of implicit interaction design, to give those working in this arena a common framework and vocabulary for design discourse. We concentrate on two aspects of implicit interaction, interaction patterns and an implicit interaction framework, which will help designers create interactions that are more socially appropriate. We advocate a design-oriented[1] approach

[1] Daniel Fallman, "Design-oriented Human-Computer Interaction," at *Proceedings of the ACM Conference on Human Factors in Computing Systems* (Florida 2003) 225-232.

that focuses on the *manner* in which the devices interact with the user. This approach complements technology-based approaches (which focus, for instance, on sensors or architectures that enable implicit interaction), or analysis-based approaches (which investigate implicit interaction through studies and controlled experiments).

Motivation

The need for an explicit framework for implicit interaction design is largely motivated by the infiltration of computer technologies into everyday life. Those who herald the promise of technologies which introduce computation into our homes, our cars, our tools and even our clothes often overlook the challenges of designing interactions for these new environments. It is clear that we cannot interact with computer devices in a car the way that we do with our desktop computer—but how *should* we interact with the device while we are driving? The answers elude us. Similarly, we all recognize that the computer need to be less needy of our attention when we are in a meeting, or on the phone, but we do not know *how* to make these interfaces less-needy. Our understandings of how to make computer interfaces ready-to-hand are based on explicit interaction, and do not translate easily to the implicit domain.

Implicit interactions are startlingly complex. We, as people, implicitly adapt our actions to changing situations without even thinking about it. We modulate our speaking volume based on ambient noise level, use smaller words when explaining things to children and hold the door open for others when we see that arms are full. These accommodations are made without explicit request, and do much to smooth our day-to-day interactions with one another. The social perspective on the design of interactions is grounded on the observation that interactive devices would be more helpful if they could do what other people do—and expect. [2] On the technical front, this requires an awareness of the outside world, some models of the implications of these sensor inputs, and some understanding of the consequences of different courses of action. It also necessitates an explicit consideration of interactions are "invisible" when they work, because they are succeed in being beneath notice. We hypothesize that well-designed implicit interactions will make interactive devices far more useful, effective, and appreciated.

Background

Early computer interaction was based on a command line interface, the equivalent of explicit human-human dialogue. The advent of graphical user interfaces and the mouse moved interaction away from typed textual commands and toward object-oriented ones, but the interaction was command-based nonetheless. Direction manipulation changed the modality of the commands, but for the most part the mouse is used for navigation rather than continuous control.[3] By and large, computers operate in the domain of *explicit interactions*. These types of interactions work well in situations where users have the attention and physical availability to direct the computer.

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[2] Byron Reeves and Clifford Nass, *The Media Equation* (New York: Cambridge University Press, 1996).
[3] Jakob Nielsen. "Non-command User interfaces" in *Communications of the ACM* 36 (April 1993), 83-99.

However, when we consider the frontier beyond the desktop, the utility of the command-based interaction breaks down. Early forays into mobile computing and ubiquitous computing have shown important shortcomings of this interaction model. In mobile computing, for instance, the same compact form factors that make personal digital assistants (PDAs) and cell phones portable also limits our ability to input commands. The fact that the devices accompany you throughout the day means that many interactions occur when you are actively engaged in another task, making inattention and partial attention a persistent issue. It is common to find that you have missed a meeting because you did not check our PDA at the right time, or to be embarrassed to have an alarm or alert come through at an inopportune time. It was concern about similar problems in the domain of ubiquitous computing that caused Marc Weiser to follow up his call for Invisible Computing[4] with a plea for Calm Computing.[5]

Many researchers working in the areas of ubiquitous computing and pervasive computing are focused on how to solve these problems by making devices "smarter." But these approaches give short-shrift to the richness of human interactions. What if our true talent as human interactants is less a wealth of intelligence so much as a measure of suave?

Interaction Patterns

When we walk into a new restaurant, we are able to get a table, order food and pay for our meal—without specific instructions about how things work there. We are able to parlay our experience with previous restaurants, despite differences, because of the familiarity of the "restaurant" genre. The well-recognized pattern of interaction is a product of convergent evolution, emerging from similar goals and constraints, as well as expectations set from other restaurants.

Since *interaction patterns* are driven in part by existing interactions, it makes sense to leverage our familiarity with human-human interactions to improve our interactions with other interactive environments, devices or agents. Understanding what a good doorman does can help to inform the interaction design of an automatic door or of a gateway into a software application. To create these *interaction analogues*, it is important to explicitly examine the sequence and structure of social transactions, paying particular attention to those parts which are most easily missed because they succeed so well in being invisible. This section examines role, sets and sequence as implicit features of interaction patterns. This set of features is not meant to be exhaustive—we expect that other generalizable aspects of interactions will be explored in greater depth by other researchers to come.

Roles

A role quickly represents an interactant's goals, capabilities, limitations and frame of reference by reference to an archetype. Roles are often communicated implicitly, through behavior, location and dress. In human-computer interactions, the roles are so often COMPUTER and USER that we lose sight of the fact that in other contexts, roles need to

[4] Mark Weiser. "Ubiquitous computing" in *IEEE Computer*, 26 (October 1993) 71-72.
[5] Mark Weiser and John Seeley Brown, "Designing Calm Technology" in *PowerGrid Journal*, v1.01, (July 1996)

be clearly communicated to help quickly and efficiently set up expectations about the nature of the interaction to come.

By making deliberate use of roles—explicitly defining archetypes and references--interaction designers can both set expectations for users and provide a role model for other interaction designs.[6] Just within the realm of dyadic (two interactant) relationships, familiar roles include DRIVER/NAVIGATOR, CUSTOMER/SERVER, and STUDENT/TEACHER. Roles need not be filled by agentic characters—a compass can be a navigator, and a vending machine can act as a server—but they do need to fulfill the tasks that are their raison d'etre.

Sets

Another way that people recognize an interaction pattern is through visual or physical form. An object's mere physical form and presence can function as part of the interactive discourse. Location and orientation of agents and objects play similarly tacit roles in framing the interaction.

Sets give actions and affordances *prominence*, which is critical for interactions that are embodied rather than verbalized. We know to attend to a performer on a stage because we understand that is where the action is. Conversely, sets also serve to *dim* potential distracters. We expect that the actions of the person in the neighboring seat are not salient to the performance. It is possible that our neighbor will jump up as a confederate, and join the actors on the stage—such "genre-bending" is accepted and, as surprised as the audience may be, they are under no misapprehension that they, too, should take to the stage. A person standing in front of the hostess' podium at a restaurant is implicitly requesting a table; a person who enters the same restaurant waiting area but faces towards the door implicitly signals that he is waiting for someone. These signals would be senseless if not for the podium, waiting area or door. These objects form part of the set for the restaurant.

As designers, we can create sets, defining the physical, visual or spatial environment in a fashion so as to disambiguate what is to be interpreted from presence, location or orientation. We give important actions prominence so that they are more easily perceived, and dim unimportant ones so they do not distract. And of course, we provide ample room for the interaction to play out.

Sequence

Much as movies and novels have a basic dramatic structure, so too do conversations and interactions follow a standard sequence. Since these sequences exist to allow communication between interactants, we can improve our designs of new interactive devices by borrowing analogous sequences from other domains.

[6] Brenda K. Laurel, *Computers as Theatre* (Reading, MA:Addison-Wesley 1991)

For example, in *Magic and Showmanship: A Handbook for Conjurers,* Henning Nelms suggests the following pattern for performing an illusion[7]. We will use it as a preliminary interaction sequence model:

1. Interest-catcher: This commands attention and directs it into the routine.
2. Introduction. Once attention has been gained, you must definitely establish the proper atmosphere and fix both your role and that of your audience.
3. Statement of Theme. The statement should be a summary in one or two sentences of ideas already explained in the introduction.
4. Kickoff point. There is always a point where the performer stops dealing in generalities and commits himself to some positive action.
5. Preliminaries. The apparatus is introduced, explained and rigged during this stage.
6. Instructions. Spare no effort to make them brief, clear and foolproof.
7. Action. This is the exhibition proper.
8. Effect. Ideally this should be short and come as a climax.
9. Ending. This covers the period form the end of the effect of the point where some completely new subject is introduced.

What is interesting about this sequence is that the trick at the heart of the illusion—the action—is sandwiched between many steps that a less conscientious magician might overlook. The early steps of the illusion serve to "ground" the interaction by garnering attention, defining roles, and establishing expectations for the action to come. The late steps help the performer to establish what the outcome was. As Herbert H. Clark explains, "To communicate is, etymologically, to "make common," to establish something as part of common ground. To do that, [speakers] have to make common all five requisites—not only content, but also participants, roles, timing and place."[8]

An interaction designer designing an automatic door might use Nelms' suggestions to magicians to consider how the door draws attention to itself, how it communicates its role as a portal, how it introduces its affordance. Such steps can sometimes be accomplished implicitly; the door's mere physical form serves to draw attention and communicate its door-ness. The designer can also look for clever ways to achieve the effects of each step: by opening a little when a person walks by, for example, the automatic door can simultaneously draw attention, define its role as a door and introduces its ability to open automatically.

Example

Here is an example of the exchange between a doorman and a person analyzed as an interaction pattern against Nelms' sequence model.

> On a street sidewalk with a entrance to building in middle of the block:
> (1) DOORMAN: [stands in front of door, wearing red uniform]

[7] Henning Nelms. *Magic and Showmanship: A Handbook for Conjurers.* (Mineola, NY:Dover Publications, 1969)

[8] Herbert H. Clark, "Pragmatics of Language Performance," in *Handbook of Pragmatics.* L.R. Horn and G. Ward (eds.) (Oxford:Blackwell 2004) 365-382.

(2) PERSON: [walks down street, in a path that will pass door]
These steps represent interest-catching and introduction. The red uniform and the motion of the walker both serve as interest catchers.
(3) DOORMAN: [spots person walking down street]
(4) PERSON: [notices doorman with red refinery in front of door, keeps walking]
The doorman's location helps set the theme, as does the walker's behavior, establishing ground.
(5) DOORMAN: [puts gloved hand on door handle]
This is the kickoff, and also acts as a preliminary, introducing the door.
(6) PERSON: [slows down a little, looks into doorway]
(7) DOORMAN: [opens door slightly]
This is the main action. It is an offer framed as a demonstration.
(8) PERSON: [keeps walking past door, turns to look down street]
This is the effect, a refusal.
(9) DOORMAN: [lets door shut, takes hand away from door handle]
The end.

Here is an example of an analogous interaction sequence with an automatic door:

On a street sidewalk with a entrance to building in middle of the block:
(1) DOOR: [exists, with sign that says "automatic door"]
(2) PERSON: [walks down street, in a path that will pass door]
(3) DOOR: [sensors notice motion down the street]
(4) PERSON: [notices door frame, keeps walking]
(5) DOOR: [makes a soft motor hum noise, as if preparing to open]
(6) PERSON: [slows down a little, looks into doorway]
(7) DOOR: [opens a little, jiggling its handle]
(8) PERSON: [keeps walking past door, turns to look down street]
(9) DOOR: [lets door shut]

This interaction analogue provides a specific and detailed illustration of how an implicit interaction can be functionally modeled as a dialogue, creating a more nuanced interaction than we normally have with automatic doors.

Implicit Interaction Framework

Interaction patterns create implicit interactions through convention. Common interactions take less cognitive attention because they comply with expectation. However, it is also possible to achieve implicitness through the *style* of the interaction, taking less attention, say, by whispering instead of yelling.

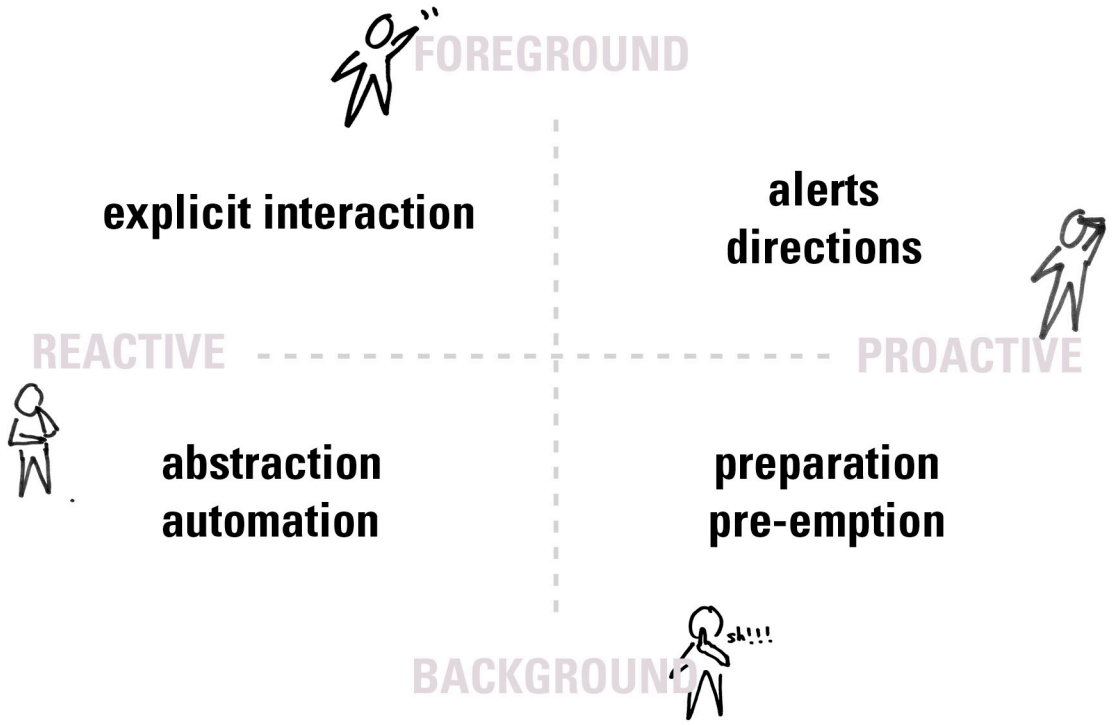

Figure 1. Implicit Interaction Framework

Figure 1 is an implicit interaction framework that characterizes interactions based on two dimensions: attention and initiative. By categorizing implicit interactions by attention and initiative, we are able to generalize about the capabilities and features of whole classes of interactions in a domain-independent fashion. The following are descriptions of the sorts of interactions typified by each quadrant.

Foreground/Reactive (a.k.a. explicit interaction)
Interactions take place explicitly and at the user's command. Such interactions are appropriate when the interaction is the primary task and is controlled by the user.

Foreground/Proactive
Device starts interaction by getting users attention. These interactions are useful for alerts, ambient displays, or for guiding user actions.

Background/Reactive
"Hidden" or "natural" user actions trigger background tasks. Such interactions can spare the user from the nitty-gritty details of a task, or help automatically perform functions like logging information.

Background/Proactive
Device infers what to do and performs without user oversight or input. This type of interaction is desirable for actions the user is not foresightful enough to take.

Now, let us examine the two dimensional variables in greater depth:

Attention

Attention characterizes the perceptual, cognitive, and motor load associated with an interaction. Activities where users actively attend to the interaction (for example, to deliberately control inputs and/or monitor outputs) take place in the *foreground* and may be spoken of as a "*foreground interaction*." Interactions where users are less conscientiously oriented towards making commands or watching for the computers signals are *background interactions*. A designer can control the prominence of various interaction elements through techniques such a*s* pointing, use of contrast, use of movement, variety, and placement.

This definition of prominence is similar to that concept of "attentional ground," defined by Buxton,[9] thusly: "What we mean by Foreground are activities which are in the fore of human consciousness - intentional activities. Speaking on the telephone, or typing into a computer are just two examples." Because he only considers the realm of user-initiated interactions—typing into a keyboard, or switching on a light—Buxton's definition conflates attention with intention. This definition is inadequate for device-initiated interactions—a cell phone ringing, or an automatic door opening. These interactions clearly take place in the foreground but are not at all intentional on the part of the user. Decoupling attention from intention gives us a separate dimension, initiative.

Initiative

The distinction of who initiates an interaction is important one in defining its implicitness. If a waiter refills your coffee because you ask him to, that is a *reactive* response to your explicit request. However, if the waiter refills your cup because he sees that it is empty, this interaction becomes implicit; even if the *proactive* act of pouring the coffee might be in your attentional foreground, the waiter is responding to a projected request or need for more coffee.

Initiative is easily over looked as a dimension in physical domains because it is particular to interaction. Eric Horvitz recognized initiative as a variable within explicit dialogue systems, and terms the interplays between proactive and reactive actions *mixed-initiative*: "In mixed-initiative interaction, both users and computers take turns in contributing to a project or an understanding."[10] It is in fact *interplays of initiative* that distinguish interaction from use—interactive objects from non-interactive ones. A door that opens because you push it is not interactive.[11] A door that opens before you push it is, as is a door which opens when you wave your badge at a reader. An electric guitar, which can only generate sound when plugged in, is not interactive, but a jukebox, even a mechanical

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[9] William Buxton, "Integrating the Periphery and Context: A New Model of Telematics" in *Proceedings of Graphics Interface* (1995) 239-246.

[10] Eric Horvitz, Carl Kadie, Tim Paek and David Hovel, "Models of Attention in Computing and Communication: From Principles to Applications" in *Communications of the ACM* 46 (March 2003) 52-59.

[11] Followers of Gestalt psychology would argue that the non-interactive door, in fact, says "open me" just by being and therefore *is* interactive. In that case, the interactive non-interactive door has initiative (but for followers of Gestalt psychology alone.)

one, is. The phenomenon of object initiative brings the field of product semiotics[12] into the realm of social psychology.

Jakob Nielsen proclaimed such proactive interactions the domain of "non-command interfaces," in which "the unifying concept does seem to be exactly the abandonment of the principle underlying all earlier interaction paradigms: that a dialogue has to be controlled by specific and precise commands issued by the user and processed and replied to by the computer." He felt, however, such interfaces were "not even dialogues" although "they obviously can be analyzed as having some dialogue content […] since they do involve the exchange of information between a user and a computer."[13] We adopt Nielsen's ideas about non-command interfaces, but feel that proactive actions are in fact dialogic, not so much "command-free" as command-implicitly-understood.
This dimension of *initiative* is continuous, not binary. If, seated at a diner, you move an empty coffee cup further from your body and closer to the outside edge of the table, this serves as a signal that you would like a refill, in part because it makes it easier for the waiter to perform this action. This is less explicit than verbally asking the waiter for a refill, and more explicit than your not signaling at all. This dimension correlates inversely to *presumption*. Reactive interactions presume very little, whereas proactive interactions are highly presumptive.

It is worth mentioning here that initiative is a very different thing than intelligence, though the one is commonly mistaken for the other. The ability to start an interaction has no inherent relationship to interaction quality, nor to the broader intellectual potential of the interactant.

Types of Implicit Interaction

By understanding the space of possible interaction styles—those that require more or less attention, those that require more or less initiative—a designer can better match an appropriate interaction to the situation at hand. In the implicit doorman example, the doorman employs proactive, low-attention techniques to signal his affordance for opening doors. He did this both through *overt preparation*, when he put his gloved hand on the door handle, and through an *enactment technique*, pulling the door open a little as a suggestion. By classifying the actions of the doorman by their general form, we are able to change domains and look for actions which perform the same function in a similar manner. These *interaction analogues* allow the designer of the automatic door to accomplish the same tasks as the doorman, softly humming in overt preparation or jiggling its handle as enactment, without slavishly replicating his actions with a doorman robot.

The implicit interaction framework provides a good way of identifying analogous interactions. Interactions in the same space are likely to face similar problems, and may be able to share solutions. The following examples of human-human, human-computer

[12] Martin Krampen, "Semiotics in Architecture and Industrial/Product Design," in *The Idea of Design: A Design Issues Reader,* V. Margolin and R. Buchanan, eds. (Cambridge, MA: The MIT Press, 1995) p. 89-103
[13] Jakob Nielsen, "Non-command interfaces." In *Communications of the ACM* 36 (April 1993) 83-99.

and human-device interactions illustrate how the same action can vary in interactional style, and how interactive techniques within each style can provide analogues across domains:

Human-human interaction

	Reactive	Proactive
Foreground	You ask your waiter for coffee, and he refills it.	Your waiter asks if you want coffee, and you offer the cup for refill.
Background	You place your coffee cup near the edge of the table, and the waiter refills it when he passes by.	Your waiter sees that your coffee is low and refills it.

Human-computer interaction

	Reactive	Proactive
Foreground	You install software updates for your computer.	Your computer asks if you'd like to have updates installed on your computer.
Background	Your computer installs software updates when it experiences long periods of inactivity.	Your computer installs updates automatically on its own.

Human-device interaction

	Reactive	Proactive
Foreground	You turn on the lights.	You are asked if you would like the room lights on.
Background	The lights turn on when you enter the room.	The lights turn on a minute before you enter the room.

A full-length interaction sequence will often transition between the different interaction quadrants. A cell phone might alert you to a call (foreground/proactive), which you then answer (foreground/reactive, a.k.a. explicit). When the call is done, you hang up (foreground/reactive) and the phone automatically logs the time, source and the duration of the call (background/reactive). Typical sequences through the space of the interaction framework constitute an interaction pattern.

Designing Better Interactions

The design of implicit interactions requires a sound judgment about what type of exchange is desirable between two parties. Not only does the designer need to decide what action needs to occur, but, very importantly, the manner in which it should take place. It is not possible to determine objectively if a design is good, only whether it is

better or if it is sufficient. Since sufficiency is inherently application-dependant, in this section we shall focus on how to make interactions better.

Christopher Alexander noted that, "The process of achieving good fit between two entities [is] a negative process of neutralizing the incongruities, or irritants, or forces, which cause misfit."[14] To reduce these incongruities, it is useful to apply two principles: the conservation of attention and conservation of presumption. Conservation of attention is straightforward and obvious, and comes down to this: Do not whisper if you should yell. Do not yell if whispering will do. Conservation of presumption is stricter: Do not presume. Consider the way most people interrupt others: they say something like, "Can I interrupt?" A literal-minded person could point out that *they just did*, but the difference between interjecting with "Can I interrupt?" or "I really want to talk to you about … [followed by extended monologue]" is that the former is less presumptive, and therefore, less jarringly obnoxious. Presumptive actions should always take place within a pattern of activity with an implicit request from somebody.

Because that last point is critical, we repeat it again: Do not presume. Presumptive actions should always take place within a pattern of activity with an implicit request. This may seem surprising, because it seems to indicate that we should never perform a new presumptive implicit interaction. How do new presumptive actions get invented? The answer: through convention. Only when a pattern of interaction has been well-established should an interface begin presumptive activity. It is a bad waiter that presumes that you want caffeinated or decaffeinated coffee if you have no prior history. It is only after you've opted for caffeine in your cup, or after you've established a regular preference for caffeinated coffee when you visit the diner, that the explicit verbal offer evolves into an implicit one, like the overt preparation of lifting of the coffee pot ("*this* coffee?" the gesture queries quietly) before pouring. Some proponents of utility-based attentional user interfaces like to present attention and utility as trade-offs, implying that a very disruptive signal could be justifiable if the transmitted value were great enough—if we were alerting people to a fire, perhaps.[15] It is just important to remember that the transmitted value of an alert is almost negligible without prior history; this is the rationale for fire drills and emergency broadcast messages.

Interactions patterns are absolutely fundamental to the design of implicit interactions. The bulk of the activities we are able to do without paying much mind only function that way because their structure is so familiar to us. Finding out exactly how such patterns are established, how much room for variation and improvisation there is within a genre or form, and exploring reinventions of these patterns is a central area for design-oriented research in implicit interactions. In addition, there is a need within the field for a set of techniques for archetypical implicit interactions, examples that are as inspirational to implicit interaction designers as Durrell Bishop's marble answering machine was to tangible interaction designers. Current forays into the realm of interaction design

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[14] Christopher Alexander, *Notes on the Synthesis of Form* (Cambridge, MA: Harvard University Press 1964)

[15] Eric Horvitz, Andy Jacobs, and David Hovel. "Attention-Sensitive Alerting," in Proceedings of UAI '99, Conference on Uncertainty and Artificial Intelligence (San Francisco: July 1999) 305-313.

patterns, such as those proposed for ubiquitous computing by Eric Chung et al,[16] are a good start into this endeavor, but as yet represent interactions at too high a level to resolve the nuances of interaction that a dialogue-based representation would capture.

A wide range of research activity is underway across a number of other fields, which will provide designers with a lot of opportunities in the arena of implicit interactions. Much of the current research in implicit interactions is focused on context-awareness, embedding sensors into devices and environments to help them acquire information not explicitly offered by the human user. These systems use background sensing to find location, to identify activity, and gauge environmental variables, among other things. The goals of these systems are often "hidden commands" which are reactive/background actions which sense a "natural gesture" to trigger an explicit response. However, these context-aware systems are primarily focused on issues of perception and interpretation;[17] not too much concern is spent on the nature of the resultant actions.

Attentional user interfaces differ from context-aware computing in that the interfaces are more explicitly interested in gauging the user's attentional state. The work of Eric Horvitz, in particular, has gone beyond inference to highlight the crucial factors of uncertainty and utility which should influence decisions over proactivity.[18] One area of AUI research that is generating a lot of attention is interruptability[19]; researchers employ information about a users computer activity, as well as environmental sensors to determine whether a person is available for interruption.[20] One can easily see how complementary research in ambient displays[21] could investigate how different *styles* of interruptions, with more or less attentional demand or presumption, might affect the interaction.

Last but not least are the ongoing studies of human interactions in fields such as psychology, ethnography and linguistics. If one lesson is to be discerned from the design of implicit interactions, it is that the power of convention should not be underestimated. The features and functions of human social convention are being discovered by those in the social sciences. This research helps ground the design of implicit interactions by establishing what it is people do when profiling each other's availability, managing uncertainty, and performing joint actions. The wealth of literature on these topics

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[16] Eric Chung, et al. "Development and Evaluation of Emerging Design Patterns for Ubiquitous Computing" in *Design Interactive Systems Conference* (Cambridge, MA: 2004) 233-242.
[17] Albrecht Schmidt, "Implicit Human Computer Interaction Through Context" in *Personal Technologies*, 4 (2&3: 2000) 191-199.
[18] Eric Horvitz, Carl Kadie, Tim Paek and David Hovel, "Models of Attention in Computing and Communication: From Principles to Applications" in *Communications of the ACM* 46 (March 2003) 52-59.
[19] Clive Thompson, "Meet the Life Hackers" New York Times (October 16, 2005) 6:40
[20] James Fogarty, et al., "Examining Task Engagement in Sensor-Based Statistical Models of Human Interruptibility" in *Proceedings of the ACM Conference on Human Factors in Computing Systems* (CHI 2005) 331-340.
[21] Craig Wisneski, Hiroshi Ishii, and Andrew Dahley, "Ambient Displays: Turning Architectural Space into an Interface between People and Digital Information" in *International Workshop on Cooperative Buildings*, (1998)

provide a very valuable research for interaction designers looking to design socially savvy interactive devices.

Conclusion

As interactive devices continue to permeate their way into our world, it is up to the interaction designers to correct their obnoxious habits, to make them more usable and useful. Designed well, implicitly interactive devices can allow us to reap the benefits of computation and communication away from the desktop, assisting us when we are physically, socially or cognitively engaged, or when we ourselves do not know what should happen next. Designed poorly, these same devices can wreck havoc on our productivity and performance, creating irritation and frustration in their wake. By taking stock of what it is we humans do when we work with one another, and using a bit of creativity in applying those lessons to the machine world, we can help make this next generation of interactive devices welcome in our world.