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Approachability: How People Interpret Automatic Door Movement as Gesture

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Abstract

Automatic doors exemplify the challenges of designing emotionally welcoming interactive systems. We attempt to broaden the automatic door's repertoire of signals by examining how people respond to a variety of "door gestures" designed to offer different levels of approachability. In a pilot study, participants (N=48) who walked past a physical gesturing door were asked to fill out a questionnaire about that experience. In our follow-up study, participants (N=51) viewed 12 video clips depicting a person walking toward and past an automatic door that moved with different speeds and trajectories. In both studies, our Likert-scale measures and open-ended responses indicate that participants viewing the door behavior prototypes show significant uniformity in the interpretation of the door's behavior, and that they attribute these motions as gestures with human-like characteristics such as cognition and intent.

Conference theme: Teaching across cultures design
Keywords: gestures, movement, emotion, welcome

Introduction

Emotional welcome is one of the goals of interaction design; designers would like to convey when users are invited to interact with designed services. This objective is particularly critical when designing systems like doors or kiosks that people use incidentally (Dix, 2002). Designers of such systems often grapple with how to apply familiar conventions to novel interaction designs, in order to provide people with an intuitive experience with new products.

Automatic doors exemplify the challenges of designing welcoming interactive systems. While people understand the basic interaction with automatic doors, any sustained observation of a building employing automatic doors will reveal numerous breakdowns: people have difficulty distinguishing automatic doors from non-automatic doors; people inadvertently trigger the doors without meaning to; people walk toward the door too quickly, or not quickly enough; people frustrated in their attempts to trigger the door before or after regular hours. Automatic doors show that extended use and familiarity alone are not sufficient to attain the critical sense of approachability; people are familiar enough with doors that they illustrate what can and cannot be accomplished through conventions of design alone.

The theory of implicit interactions (Ju, Leifer, In press) posits that people rely on conventions of implicit interaction to subtly communicate queries, offers, responses, and feedback to one another, and that these interactions can be applied analogously to the design of interactive devices to improve people's ability to "communicate" with interactive devices. For example, the "offer" is one type of implicit interaction; it performs the critical function of alerting potential interactants to the possibility of a joint action (Clark, 1996). A deeper understanding of human-human implicit interaction could greatly improve user interactions with interactive devices, by enabling interaction designers to improve perceived welcome, for example, or to enable peripheral interaction with devices (Buxton, 1995).

This research attempts to broaden the automatic door's repertoire of signals through conventions of communication, rather than conventions of door design. We examine how people respond to a variety of "door gestures" designed to offer different levels of approachability. We expect that the door gestures will be interpreted in a similar fashion by a range of study participants, even when the door gestures themselves are non-conventional. More specifically, because the interaction type is an "offer" we expect that different gestures will affect people's interpretation of the door's approachability. Thus, this study is an empirical test targeted at both improving interactive system design and at testing the broader theory of implicit interactions.

Related Work and Theory

Much of prior work in the arena of product design in general, and door design in specific, has focused on the mechanics of making doors usable, both physically and cognitively. Norman, for example, famously examined how poor planning of the physical cues in door design leads people psychologically astray (Norman, 1988); this is the reason that poorly designed "push" doors that feature "pull" handles are called "Norman doors." However, in later work, Norman notes the importance of addressing the visceral, behavioral and reflective aspects of emotional cues to make designs truly work (Norman, 2004). One of the critical elements to designing with "emotionally intelligence" is to account for people's appraisal of emotional expression (Salovey, Meyer, 1990); non-verbal communication is often used for expressing feelings, emotions, motivations, and other implicit messages (Argyle, 1988). The instinctive reflex to interpret emotional expression in perceived actions has been demonstrated to cause people to attribute emotional motivations to non-human and even non-animal actors. For instance, Heider & Simmel (1944) found that people interpreted moving objects in the visual field "in terms of acts of persons." Subsequent studies by Michotte involving simple depictions of two moving balls showed that while some movements elicited "factual" descriptions, others caused people to attribute motivations, emotions, age, gender and relationships between the two objects (Michotte, 1962). This research complements more recent research by Nass and Reeves, which indicates that people interpret computers and other media technologies as social actors (1996). These studies by suggest that neither voice nor facial features are required to trigger social attribution of actions. Latour observed that people ascribe human agency to self-closing doors ("door grooms," in French parlance) because they have been designed to take over a human task; this encourages an anthropomorphic interpretation of the door actions despite the door's lack of human-like form (1992). This suggests that designers can design interactive environments to signal both subtly and expressively, much as animators create subtle expressiveness in otherwise inanimate objects (Lasseter, 1987).

Implicit interactions often use emotion to serve the important pragmatic function of signaling when joint actions can or should take place between two or more participants. While implicit interactions may precede, prevent, or augment verbal or other explicit communication, they mediate interaction without requiring "linguistic" communication (Clark, 1996). The term "implicit" refers to the fact that people are able employ these types of communication without conscious awareness; indeed, the anthropologist Hall labeled the use of body, space and motion the "hidden dimension" of human interaction (Hall, 1966). However, these types of interactions can also function when one or more of the interactants employ them consciously.

The use of physical movement and other implicit means of signaling can be thought of as an extension to theory of affordances. Affordances are variously described as the actual (Gibson,1979) or perceived (Norman, 1988) properties of an object that relate its potential for use. Gaver extended the notion of affordances into the realm of the interactive with the concept of sequential affordances, which are revealed over time (Gaver, 1991). Objects employing these complex affordances may be thought of as implicitly communicating potential for action through their dynamic behavior.

While there is substantial overlap between the design principles suggested by the theory of affordances and that of interaction design, the distinction between the two is that theory of affordances rests on people's perceptual abilities as a means of discovering potential use, whereas the theory of implicit interactions relies on people's communicative abilities regarding potential use. Affordances would indicate whether one could enter a building, because they would or would not perceive a passageway. Implicit interactions, on the other hand, would indicate whether one was welcome to enter the building.

STUDY 1: PHYSICAL PROTOTYPE PILOT

Study Design

As an exploratory pilot study, we employed a field experiment on gesturing doors. We used Wizard of Oz techniques (Dahlbäck, Jönsson, Ahrenberg, 1993) to gesture a physical building door at participants who happened to be walking near the door during its deployment (N=48). The primary interests of this pilot study were (1) how people interact with the door and (2) how do they interpret the dynamic motions of the gesturing door. We took note of whether the participant was walking toward the door or walking by the door at the time of their encounter with the gesturing door. Over a three-day period, we tried three different door trajectories: open, open with a pause, and open, then quickly close. Each participant only saw one of the door trajectories; hence, it was a between-participants study.

Materials

For this experiment, we selected one of a set of double doors that featured a large pane of glass that enable people to see into the building. A human operator stood to the side of the door, out of view from passers by, and acted as a wizard, pushing the door using a mechanical armature attached to the door's push bar. We used gaffer's tape to hide the armature and Contact Paper to obscure the windows to the sides of the door to create the illusion that the door was opening on its own. (See Figure 1 for the experiment as seen from inside the building and see Figure 2 for the view from outside the building.)

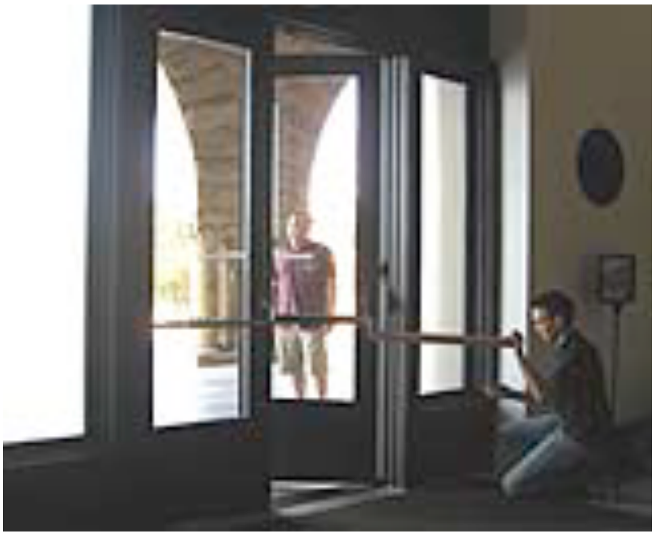

Figure 1. Wizard of Oz setup. A hidden door operator uses a mechanical armature to gesture the door.

The paper questionnaire contained two open-ended questions: "What did you think was happening when you saw this automatic door move?" and "Assuming it functioned properly, how did you interpret the door's movement?" The questionnaire also included closed-ended questions that queried participants on 10-point scales with the following questions and anchors:

How did you feel about the door?
(1) very negative – (10) very positive
The door seemed to intend to communicate something to me.
(1) strongly disagree – (10) strongly agree
The door seemed to think when it communicated with me.
(1) strongly disagree – (10) strongly agree
The door was reluctant to let me enter.
(1) strongly disagree – (10) strongly agree
The door was welcoming me.
(1) strongly disagree – (10) strongly agree
The door was urging me to enter.
(1) strongly disagree – (10) strongly agree

Procedures

The procedure for the study required three to four experimenters. One was the door operator mentioned earlier. Another experimenter acted as a monitor, waiting casually outside of the building and surreptitiously triggering an alert to the door operator inside via walkie-talkie when pedestrians neared the door. The other experimenter(s) approached the pedestrians with the paper questionnaire after they had seen the gesturing door move.

Figure 2. Person walking (a) by and (b) towards the door. Note the monitor on the right.

Only those people who approached the door from the direction shown in Figures 1 and 2 were chosen to encounter the gesturing door because anyone approaching from the other direction might have seen the door operator and armature. Experimenters approaching people first queried participants to gauge whether they had noticed the door's motion before giving them a paper questionnaire. Some people declined to fill out the questionnaire; the most common explanations for non-participation were lack of time and inability to speak English. Most people (48 out of 64) opted to fill out the questionnaire and many even discussed the study with us at some length. Date, time, participant gender, and experimenter condition were noted on the back of each questionnaire.

Data Analysis

Consistent with this prior work, the following studies use uniformity of participant interpretation as the standard for evaluation.

We used univariate analysis of variance (ANOVA) to analyze the data, using door trajectory as the independent variable and participant walking direction as a covariate. (Because participants were not randomly assigned to walking direction conditions, walking direction was not used as a full independent variable.) Each questionnaire item was analyzed as a dependent variable in an ANOVA.

In addition to the statistical analyses, we present descriptive statistics and observations from this pilot study that fed into the next iteration of this study design.

Quantitative Results

During the experiment, 64 people nearing the door noticed its motion; 48 of them opted to fill out the questionnaire. An additional 38 people did not notice the door's motion. Distributions of door motions and walking trajectories for participants who noticed the door move and filled out the questionnaire are reported in Table 1.

Table 1. Frequency distribution of pilot study participants

	Open	Open with pause	Open, then closed	Total
Walking by	11	7	19	37
Walking toward	2	4	5	11
Total	13	11	24	48

Door trajectory had a significant influence on valence of feelings toward the door, perceptions of reluctance, welcoming, and urging on the part of the door. Walking direction had a significant influence on perceptions of the door as urging one to enter. These results are presented in Figure 3 and are further described in this section. Differences in sample sizes are due to non-responses by some participants to some questions.

Door trajectory significantly affected the valence (negative to positive) of participants' feelings toward the door, $F(2,44)=5.37$, $p<.01$: open ($M=6.62$, $SD=2.06$), open with pause ($M=6.55$, $SD=1.57$), and closed ($M=5.06$, $SD=1.27$). Walking direction was not a significant factor. Door trajectory also significantly affected how reluctant the door seemed to be, $F(2,43)=6.73$, $p<.01$: open ($M=1.67$, $SD=0.78$), open with pause ($M=2.18$, $SD=1.66$), and closed ($M=4.25$, $SD=2.77$). Again, walking direction was not a significant factor.

Door trajectory also significantly affected how welcoming the door seemed to be, $F(2,44)=3.45$, $p<.05$: open ($M=5.92$, $SD=3.33$), open with pause ($M=6.73$, $SD=3.44$), and closed ($M=4.00$, $SD=2.59$). Again, walking direction was not a significant factor.

Finally, walking direction significantly affected how urging the door seemed to be, $F(1,44)=1.38$, $p<.05$: walking by ($M=3.57$, $SD=2.44$) and walking toward ($M=5.82$, $SD=3.31$). Door trajectory did not significantly affect perceptions of the door as urging one to enter the building.

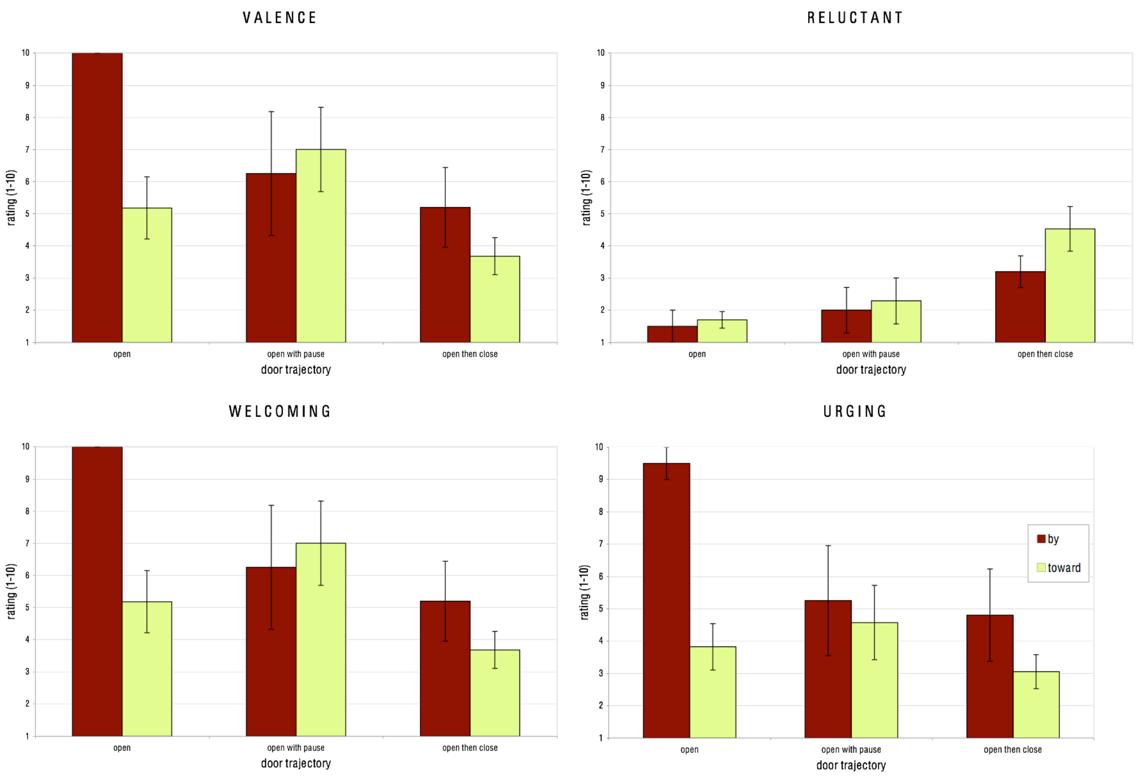

Figure 3. Mean +/- std. error values for Study 1 Door Perception Factors

There were no significant results for questions about apparent intention or apparent cognition of the door.

Qualitative Results

Written responses to the open-ended questions were too short for any meaningful response coding. The average length of response was 29 characters for the first question (*M*=29.4, *SD*=14.8), and 19 characters for the second (*M*=19.0, *SD*=15.9). The likely cause for the brevity of response is that participants filled the questionnaires out while standing, and on their way to another destination.

Discussion

The results of the pilot study were promising in that they suggested uniformity in interpretations of door motions. Even in the noisy world of people going about their everyday lives, people showed consensus in their responses to the door motions.

Other insights gained from this pilot study came from qualitative observations and discussions with participants after they finished the questionnaire. One participant was a retail designer who was interested in the study because the door's motion caught his attention and made him curious about what was inside of the building; the goal of shops is to entice potential customers to walk through their doors.

One important observation for consideration in real field deployments of such systems are those people who did not notice the moving door. They tended to be walking and talking with others, talking on their mobile phones, listening to music players with headphones or walking very quickly, seemingly in a rush to some other destination. People are not always strolling idly down the street; they are often preoccupied, even during the summer on a nearly empty college campus.

One issue with this pilot field experiment was that participants who walked through the door also ended up seeing the door operator before they filled out the questionnaire. Fortunately, the majority of the data came from people walking by the door rather than toward it.
Another issue with this pilot field experiment was that participants who were unhappy with the door were also quite unhappy with the experimenter who requested their time to fill out the questionnaires. In particular, those participants who were walking toward the door and had the door shut in their faces seemed personally offended; several people were consequently unwilling to fill out a questionnaire "for the door."

STUDY 2: VIDEO PROTOTYPE EXPERIMENT

Based on the findings and identification of weaknesses in pilot study, we decided to conduct a more controlled experiment to further test people's responses to door gestures. In the video prototype study, participants were shown 12 different types of gestures using video clips embedded in a web-based questionnaire.

As in existing research (Heider, Simmel, 1944; Michotte, 1962), these studies engage participants in an "interpretative" role (where they are asked to read the interaction) rather than an "interactional" role (where they are asked to engage in the interaction). Although this method sacrifices some ecological validity, the video-prototype study enables better "participant" and door interactions, and cleaner isolation of feelings toward the door rather than toward the experimenter or study. In addition, this video prototype could be run as a within-participants study, thus reducing the possibility that our inadvertent selection effects might be skewing our results across the conditions.

Study Design

This study added one new dimension, door speed, to the previous study design. Using a 2 (person walking direction: walking by vs. walking toward) x 2 (door speed: slow vs. fast) x 3 (door trajectory: open vs. open with pause vs. open then close) within-participants experiment design, we investigated the effects of both the door and the passerby's actions in this human-door interaction. Participants were recruited from a university community (N=51).

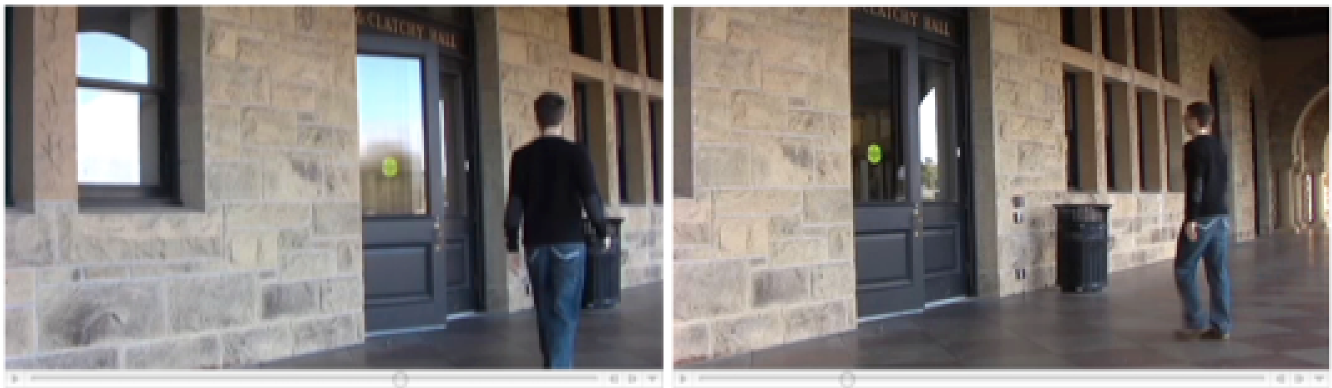

Figure 4. Screenshots of video of person walking by (left) and toward (right) the gesturing door

Materials

We performed a web-based experiment in which participants were shown 12 web pages that each contained an embedded video of a human-door interaction and questionnaire items. The clips were randomly ordered to address ordering effects. These 12 videos included every combination of our three independent variables: person walking direction, door speed, and door trajectory. Like the pilot study, the videos showed door gestures performed by a hidden door operator. On each page, participants were asked to play the video, imagining themselves as the person in the video. To prevent participants from merely reading the person's reaction as opposed to imagining what their reaction would be, we chose a camera angle that hid the walker's face and ended the clip before the person walked through the door or physically reacted to the door's gestures. Video clips ranged from 4 to 9 seconds in length, were sized at 540 x 298 pixels, and were encoded using Apple Quicktime format. (See Figure 4.)

Procedure

Participants who volunteered for the study were directed to the web page with gesturing door videos and questionnaire items. After watching each video, participants were asked to describe their experience with the door from the perspective of the person in the video, and to describe what they thought the door was communicating. They were then asked to rate the strength of their agreement or disagreement with three statements about the door, including how reluctant, welcoming, and urging the door seemed. These factors were the significant factors in the pilot study.

Data Analysis

Using Principle Component Analysis, we found that the three Likert indices (welcoming, urging, and reverse-coded reluctant) constituted a single and highly reliable factor, with Cronbach's α =.91. Therefore, we combined them into an unweighted averaged single factor, approachability. Open-ended responses were coded and averaged across coders for valence (negative, neutral, or positive), apparent cognition (0 or 1), and apparent intent of the door (0 or 1) by two independent coders, who were blind to the experimental conditions. Inter-rater reliability was reasonable: Cronbach's α values of .714, .616, and .723, respectively.

Results

Unlike the pilot study, the video prototype study elicited far more descriptive responses to the open-ended questions. Average length of responses was 75 characters for the first question (M=75.1, SD=51.2), and 53 characters for the second (M=53.1, SD=42.1). This far exceeded the lengths from the previous study, despite the fact that each participant filled out 12 times as many questions. Descriptions of the door included descriptions that implied apparent cognition and intent, e.g., "Insulted, it acknowledged my presence but judged me and said no!" and, "The door wants me to come in, but doesn't want to appear more eager to have me enter than I am." Other types of descriptions did not express any apparent cognition or intent at all, e.g., "I wonder why the door blew open," and, "I walked by a door and it slowly opened."

After all of the descriptions were coded and averaged across coders, we used a within-participants full-factorial repeated-measures analysis of variance to investigate the effects of each of the three independent variables (person walking direction, door speed, door trajectory) upon each of the four dependent variables (approachability factor, valence of person's response, apparent cognition attributed to door, apparent intent attributed to the door). They showed highly systematic responses amongst participants.

The door's trajectory had the most far-reaching effects across all dependent variables: approachability ($F(2,30)=70.91$, $p<.001$), valence ($F(2,88)=43.31$, $p<.01$), apparent cognition ($F(2,50)=5.64$, $p<.01$), and apparent intent ($F(2,42)=3.59$, $p<.05$). In general, the door that opened and then closed before the person got to the door made the door seem more negative, more intentional, and less approachable, whereas the door gesture that simply swung open was read as approachable but not necessarily cognitive or intentional. (See Figure 5, Row 1.)

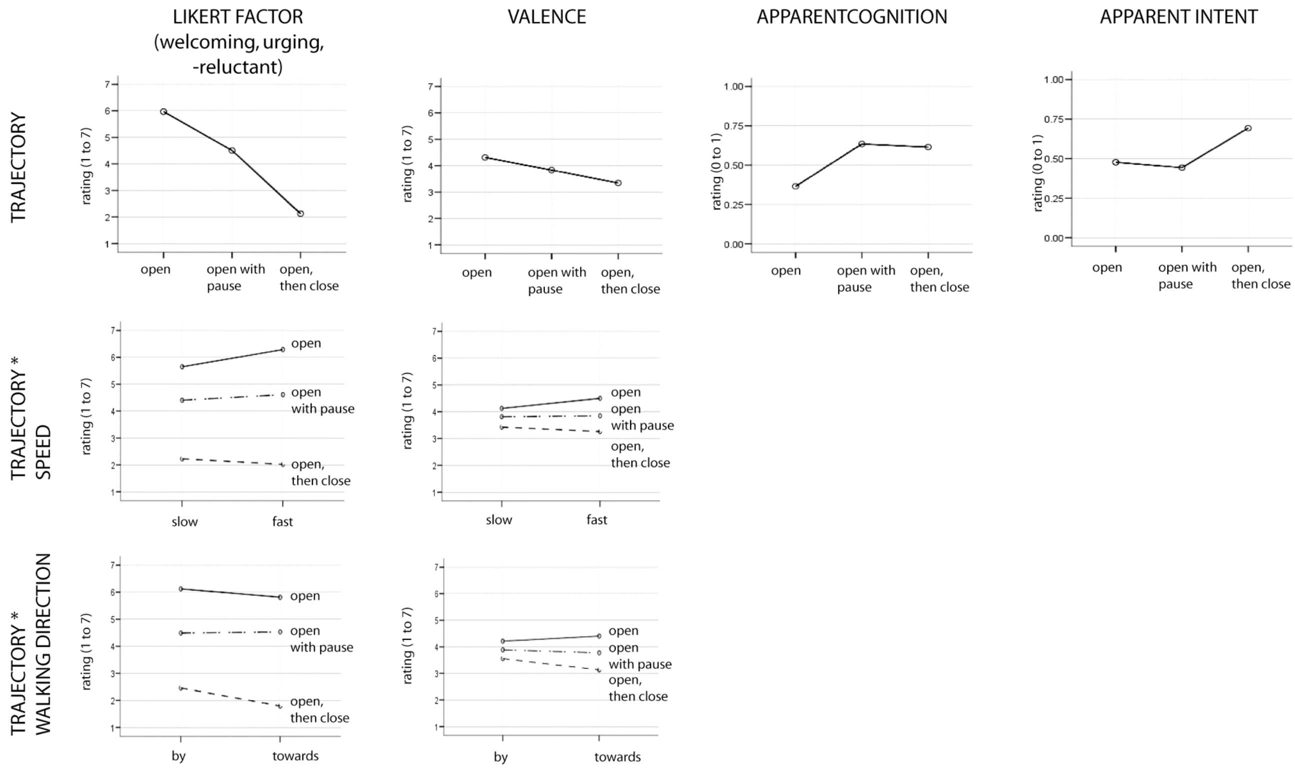

Figure 5. Mean values for significant and nearly significant main effects on responses toward gesturing door trajectories

Several two-way interactions were significant or nearly significant. Faster door speeds showed a trend toward exaggerating the effects of door trajectory. It significantly influenced valence, $F(2,88)=6.55$, $p<.01$, and nearly significantly influenced approachability, $F(2,30)=2.61$, $p<.09$. Similarly, the walking direction of the "participant" showed a trend toward exaggerating the effects of the door trajectory. It significantly influenced valence, $F(2,88)=6.40$, $p<.01$, and nearly significantly influenced approachability, $F(2,30)=2.76$, $p<.09$. (See Figure 5, Rows 2 and 3.)

Discussion

The core finding of this study is that people's interpretations of door gestures are highly coherent across several dimensions of door motion; despite the novelty of gesturing doors, untrained interactants "intuitively" read the gestures in systematic ways that were very consistent with the findings in pilot study 1. This suggests that people have a common understanding of door interaction and interpretation of the meaning of door gestures, possibly comparable to interpretations of human gestures (McNeill, 2005). This agreement supports the notion that door motion can provide an effective means of implicit communication.

Since one of the major obstacles to implicit interaction development is the catch-22 that it is difficult to assess people's interpretations of implicit actions without distorting the effect by asking about them explicitly, the video prototype technique employed in this study is a methodological contribution to this area of research. While it will take more subsequent studies to see if people evaluating these interactions in an interpretative role are reasonable predictors of how people would feel in an interactive role, the coherence of these two studies is promising.

CONCLUSIONS

These two experiments indicate that door trajectory is a key variable in the doors expression of welcome, with door speed and the interactive context in which the door is opening acting as amplifying factors influencing how the door's gestures are interpreted emotionally. The wide range of expression available with only one physical degree of freedom suggests that designers can trigger emotional appraisal with very simple actuation; unlike previous systems, which employed anthropomorphic visual or linguistic features, our interactive doors were able to elicit social response by using only interactive motion to cause attributed cognition and intent. If designers can convey different "messages" in such a highly constrained design space, it seems reasonable to extrapolate that more information could be conveyed with more complex ubiquitous computing and robotic systems.

While this study focused on doors, our broader goal was to experiment with welcoming users to engage in joint action. We hope to build on the theory of implicit interactions by applying the same implicit interaction techniques to more novel applications. The techniques explored here could be extended by other interaction designers in a variety of applications: in interactive kiosks patterns to proactively indicate to users what services are provided (Buxton, 1997), in word processors interfaces to proactively offer assistance formatting letters or printing without use of insufferable talking paperclips (Xiao, Catrambone, Stasko 2003), or by future work environments to indicate selective access to different badge holders (Weiser, 1991). This research will assist designers of interactive devices by expanding the repertoire of implicitly communicative conventions that can be employed in the design of interactive systems that welcome users.

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