How Interface Agents Affect Interaction Between Humans and Computers

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Abstract. For many years, the HCI community has harbored a vision of interacting with intelligent, embodied computer agents. However, the reality of this vision remains elusive. From an interaction design perspective, little is known about how to specifically design an embodied agent to support the task it will perform and the social interactions that will result. This paper presents design research that explores the relationship between the visual features of embodied agents and the tasks they perform, and the social attributions that result. Our results show a clear link between agent task and agent form and reveals that people often prefer agents who conform to gender stereotypes associated with tasks. Based on the results of this work, we provide a set of emerging design considerations to help guide interaction designers in creating the visual form of embodied agents.

1 Introduction

For many years the HCI community has harbored a vision of interacting with intelligent, embodied computer agents. Such agents, if appropriately designed, could play an instrumental role in how we interact with technology products and systems. For example, using an embodied agent for training and monitoring applications could mean that people interact with technology in a more natural and social manner. .

Fueled by images in movies and television, and through the technology industry's visions of the future — such as Apple's Knowledge Navigator [1] — the idea of naturally and socially interacting with embodied agents to control computers has become almost a cultural expectation. However, the reality of these agents has remained far from the vision.

Apple's Guides project provides an example of one of the first interfaces to address this idea [2, 18]. Researchers chose to use static black and white renderings of people dressed in historic costume and situated in historic contexts in order to aid users in the navigation of a multimedia database. In evaluating their design, researchers discovered an unexpected social attribution when people used the product. Users viewed the

multimedia content as being the opinion of the visualized guides instead of the more anonymous and unbiased content of an encyclopedia. This discovery hinted at an as yet not understood potential for embodied agents to socially shape people's interaction with computers. This discovery motivated research into the effects interactive, embodied agents produce and the development of commercial products intending to leverage this effect and improve the user experience.

Today the HCI community remains divided on the idea of embodied agents. Most HCI research focusing on the efficiency and effectiveness of interfaces has failed to demonstrate that embodied agents can provide significant benefit [9]. Additionally, commercial applications that have attempted to operationalize a social agent, such as Microsoft's Clippy, have failed to demonstrate a significant improvement in the experience of interacting with computers.

Other important research has demonstrated that people interact with computers as if they were social actors, even when the computer does not take an anthropomorphic or embodied form [21]. By adding an embodied form to mediate the human-computer interaction, designers choose to make the social aspects of the interaction more explicit. And as computing devices continue to move out of the workplace and into more social and leisure-driven environments, the idea of what a computer is, the role of the interface, and the social interaction that results continues to change. Embodied agents, through their form, clothing, facial expression, and gestures provide designers with "semiotic shortcuts", allowing them to bring the rich communication channels found in human social interaction into the interface [8]. Additionally, embodied agents in an interface become an embodiment of the application's content [18] and have the potential to communicate value positions in the same way spokes models and endorsers communicate company brands [10].

Currently many interaction designers are being asked to design embodied agents, but they lack sufficient guidelines to fulfill this request. Our research addresses this problem through a systematic investigation. We have conducted two studies that explore the relationship between the visual features of embodied agents and the tasks these agents are intended to perform. The first study looked at a representative set of agents that were found in research and industry [23]. The second study, reported in this paper, employs agents we designed ourselves to explore whether these embodied agents produce the same effects we observed in the first study. The main findings of both studies include (i) that people prefer agent forms that conform to gender stereotypes for different tasks and roles; and (ii) that men prefer embodied agents more than women do. In this paper, we describe the two studies and provide a set of emerging design implications to help guide interaction designers in creating the visual form of embodied agents.

2 Related Work

Many researchers have investigated the use and effect of embodied interface agents. These studies have produced results relating to agent form — appearance, gender, gesture, location, etc.; agent interaction — agent's use of text or voice, user's use of text or voice, use of small talk, humor, proactivity, etc.; agent task — the service the

agent provides for the user; and agent performance — how well the agent completes the task. In framing this research, we focus on research related to agent form, social attributions of the agent based on agent form, and perceptions of the agent based on the tasks it performs.

Early investigations of agent form demonstrated that embodied agents produce a feeling of social presence for users [22]. In addition, this feeling of presence and sociality increases when the embodied agent looks like a person instead of taking an animal or an abstract form [12].

Studies also explored the differences in the quality of the embodiment, for example, whether the agent appears as a simple cartoon, a more realistic 2D drawing, a 3D computer generated image, or as a photograph of a real person. In general, researchers have found few significant differences in people's perceptions based on the quality of the embodiment [4, 9, 12, 13, 15, 19, 20]. Agents with human forms were perceived as more intelligent when they had higher quality renderings [19, 20]. However, when considering agents with animal forms, participants indicated no difference in intelligence between a cartoon dog and a photo realistic dog [21].

One of the main themes covered in these explorations was perception of intelligence. Researchers speculated that designers should consider not using a human or highly realized human form for an embodied agent, as it might indicate more intelligence than the actual agent could deliver, and this mismatch between expectation and performance would produce a negative user experience [12, 15]. Studies do show that agents with human form are perceived to be more intelligent than agents that used an animal form or some other form [12, 13, 20]. However, once people have interacted with an agent, the differences in perception of intelligence go away, indicating that the performance of the agent is more critical to the perception of intelligence [13, 19, 20].

In looking more closely at the appearance of agents that take a human form, Walker et al. discovered that people prefer interacting with an agent that smiles; however, they provided more information to an agent with a stern face [22]. Additionally, Cowell and Stanney found that people prefer young looking agents that appear to have their same or a similar ethnicity [5], upholding the likeness effect that is commonly reported in human-human interaction literature.

Very few studies have explored issues related to preferences for different genders of human agents, or issues around preference differences between male and female users. One study found that men and women did not have a gender preference in the selection of an embodied agent with a human form [5]. Another found that people did not perceive a difference in the intelligence in male and female looking human agents [13]. Finally, one study did find anecdotally that women were more likely to talk about an agent using a personal pronoun such as he or she than men, indicating a difference might exist in the way men and women personify human agents [4].

In reviewing the literature, much ground has been covered, but many questions remain. For example, while the surface issues of form have been explored, none of these studies have explored the relationship between the form and the role the agent plays. Our research advances the state of the art by directly addressing this critical issue. We build on the framework developed by Catrambone et al. developed to find relationships between agent form, agent task, and demographic details of users [4].

3 Study 1 Recap

Study 1 was previously reported in [23]. We provide a brief overview of agents used and results in order to more easily make the comparison to Study 2.

Study 1 explored the relationships between the appearance of an agent, the task the agent performs, and the gender of the user. We hypothesized that humans would be preferred over animal and abstract forms, that differences would exist in preference for agents among male and female participants, and that gender stereotypes would play a role in which agents were perceived to be the most suitable for different tasks.

To explore these hypotheses, we collected a large number of agent samples from commercial products and research efforts, shown in Figure 1. We conducted a PCAM (Product Content Analysis Method) study to understand the effects of agent and task. This method has been used successfully by design researchers in the past to explore how well selected design features convey to the users of a product a particular product function or theme [7, 11]. Participants were asked to rate each agent for its appropriateness for a particular tasks. Tasks were held consistent for Study 1 and Study 2 and are shown in Table 1. Tasks were classified into four groups: entertainment/social, information, work, and learning tasks.

Figure 1. Forms of agents used for Study 1 (names were removed for the study).

Results from Study 1 (provided in Table 2) showed that human agents were preferred over non-human agents; female agents were preferred over male agents; and that male participants preferred agents more than female agents, especially when the agent was human.

Table 1. Agent tasks used for the study.

Task classification	Tasks
Entertainment and social	Museum tour guide, Travel planner, Concierge, Matchmaker
Information	Reference librarian, Movie recommender, Real estate agent, Lab Technician
Work	Receptionist, Financial advisor, Customer service representative, Medical Advisor
Learning	Therapist, Athletic trainer, Tutor

Table 2. Summary of agent comparison t-test results for Study 1. Surveys used Likert scales from 5 (most preferred) to 1 (least preferred).

Agent Comparison	Mean x	Mean y	Difference	p-value
Human forms to non-humans form across all participants	2.840	1.747	1.093	p<.001
Human-female forms to human-male forms across all participants	3.163	2.729	0.434	p<.001
Animal forms to other forms across all participants	1.854	1.701	0.153	p<.001
Male participants to female participants for all agents	2.581	2.331	0.25	p<.001
Male participants to female participants across all agents with human forms	3.040	2.698	0.342	p<.001
Male participants to female participants across all agents with non-human forms	1.809	1.720	0.089	p<.001

In addition, it appears that gender stereotypes do play a role when viewing embodied agents (Figure 2). Even though researchers have studied the effect of gender stereotypes in speech user interfaces, this effect has yet to be reported for embodied agents [17]. In our study, both men and women preferred female agents, and these agents were chosen for jobs that are viewed as being traditionally undertaken by women, for example, librarian and matchmaker. These findings support the notion that gender stereotypes found in society at large do play a role in shaping people's expectation of agent form. The stereotype idea helps explain the higher rating of the female agents for receptionist, realtor, and librarian, and the higher rating for the male athletic trainer.

As a result of these findings, we decided to undertake the same study with agents of our own design. We wanted to see if the same effects might occur for agents that are consistent in appearance, with subtle cues that differentiate male agents from

female agents and abstract agents, as opposed to the stereotypical agents featured in Study 1.

Figure 2. Mean satisfaction score for agent instantiation across agent tasks. An asterisk indicates statistically significant ($p < .01$).

4 Study 2 Overview

In Study 2, we again embarked on a design study, first assembling agent examples from commercial products, research projects, and science fiction and media. A total of 109 examples were coded for the presence and absence of features and grouped into four categories: abstract, cartoon, simple, and complex. For each category, the most common set of overlapping features determined what features were contained in that category. For example, the abstract category contained only the features head, eyes, and mouth.

Next, designs were generated based on the categories and corresponding feature sets. Abstract, cartoon, simple, and complex two-dimensional representations were generated using a vector-based graphics program; three-dimensional renditions of these representations were generated using a three-dimensional rendering package. Each agent was scaled to the identical size and screen resolution. A total of 24 agent representations (abstract, two and three-dimensional; male and female cartoon; and male and female complex, two and three-dimensional) were selected for the final study (Figure 3). For each category, the agent was represented from front view, side view, and three quarters view.

Figure 3. Agent renderings with labels created for Study 2. (Labels were not used in the study). Agent designs were held constant except for minimal cues to suggest male or female gender, such as color, hair style, and presence or absence of eyelashes.

4.1 Hypotheses

Our second study again explored the relationships between the appearance of an agent, the task the agent performs, and the gender of the user. This time, however, we worked with agents of our own design, the design of which were held consistent except for minimal cues that suggested gender. We reasoned that by holding the design consistent, we could better understand the effects of gender and stereotyping. For Study 2, we hypothesized:

1. H1: Female agents would be preferred over male agents and abstract agents, even with minimal cues to suggest difference in gender.
2. H2: Differences would exist in preference for agents among male and female participants.
3. H3: Gender stereotypes would play a role in which agents were perceived to be the most suitable for different tasks.

4.2 Method

A PCAM (Product Content Analysis Method) study was deployed as a web-based survey. The PCAM can help designers confirm their intuitions about users' perceptions of particular product features, and examine tradeoffs involved in designing these features. Using this method, images of products (in this case, agents) are collected and rated by participants using 7-point Likert scales. The data is then compared with the

example agents using statistical regression analysis. This allows for designed features of the agent heads to be examined singly or in combination to participants' responses, controlling for age and gender.

In the survey, participants rated each of the 24 agent instantiations for 15 tasks. Tasks were based on the Strong Campbell Interest Inventory [3] and our review of agent literature. Each participant viewed the agents in random order and rated each of the 15 tasks. Responses were collected using a 5-point Likert scale, where 5 was a "highly likely" rating and 1 was a "highly unlikely" rating.

Due to the systematic determination of the agent designs, for Study 2 we coded only for agent gender (male or female); agent type (cartoon, 2D, or 3D); angle of view (front, quarter, or side); and human or abstract. This resulted in a 24 agent by 10 feature matrix.

A total of 24 participants completed the study. They ranged in age from 18 to 36 with the average age of 25.7; 9 were male and 15 were female.

5 Study 2 Results

In general, our hypotheses were supported for Study 2, and the results showed preferences for agents and gender effects that were similar to the results found for Study 1. A variety of Standard Least Squares tests were performed to check for statistical significance based on several variables as shown in Table 4 and provided the following four main results:

1. Participants rated human agents significantly higher than the abstract agents.
2. Participants rated human-female forms significantly higher than agents with human-male forms.
3. Male participants rated all agents significantly higher than female participants.
4. Male participants rated human agents significantly higher than female participants.

Table 4. Summary of results of agent comparisons.

Agent Comparison	Mean x	Mean y	Difference	p-value
Human forms to non-humans form across all participants	2.599	1.905	0.694	p<.001
Human-female forms to human-male forms across all participants	2.178	1.79	0.388	p<.01
Male participants to female participants for all agents	2.177	1.783	0.394	p<.01
Male participants to female participants across all agents with human forms	2.313	1.815	0.498	p<.001
Male participants to female participants across all agents with abstract forms	1.771	1.689	0.082	ns

Figure 4 shows participant ratings based on the agent’s classification and the participant’s sex. The graph has been sorted by highest mean for all participants. The figure shows that human agents were preferred more than abstract agents, and that male participants preferred human agents more than female participants.

Figure 4. Mean satisfaction scores for agents by participant gender and agent classification.

The next analyses, shown in Figures 5 and 6, are interest groupings as used in Study 1. Male and female agent representations are significantly above abstract ratings. In addition, across all of the tasks, the preference for male agents never exceeded preferences for female agents.

In general, our hypotheses were supported for Study 2. When using agents of consistent design, featuring minimal cues to suggest gender and no suggestions of task stereotype, the data showed that human agents were preferred over abstract agents; female agents were preferred over male agents; and that male participants preferred agents overall more than female participants.

Most interesting was the finding that female agents were again chosen for jobs that are perceived as traditionally being undertaken by women, for example, librarian and matchmaker. Once again, these findings provide evidence that gender stereotypes found in society do play a role in shaping people’s expectations of agent form, even when the cues used to suggest gender are minimal. The preference for a male agent as an athletic trainer can also be explained by the preference for gender stereotype, as men are often viewed as having a stronger connection to athletics.

6 Overall Discussion

This paper presented two studies seeking a relationship between agent appearance, gender of the user, the task undertaken by the agent, and the social attributions that result. Our first study showed that agents with human forms were significantly pre-

ferred over agents with non-human forms, that agents with female forms were rated higher than agents with male forms, that men rated human agents higher than women, and that task plays a role in how agent forms are interpreted. In the second study, human agents were also ranked significantly higher than abstract agents, agents with female forms were rated higher than agents with male forms, and men rated all agents higher than women.

Figure 5. Mean satisfaction scores for male and female participants across agent tasks.

Figure 6. Mean satisfaction scores for agent instantiation across agent tasks.

Although the agents used in Study 1 and Study 2 differ — the agents collected and used in Study 1 rely heavily on gender and stereotyping, and the agents designed for

Study 2 are consistent, with minimal cues to suggest gender differences — the same consistent findings exist for both studies. In addition, gender stereotypes appear to play a role in the selection of agents, with female agents being preferred for matchmaker and reference librarian in both studies, and male agents being preferred for athletic trainer in both studies.

7 Design considerations

Based on the literature, and the results of our studies, we offer the following design considerations for the design of embodied agents. These initial guidelines, we expect, will be built on to become more specific design recommendations when agents are designed for specific tasks and domains.

1. Gender is a primary design feature and should be a critical consideration in the design of embodied agents. The role that gender plays in a human-computer interaction cannot be underestimated. It may be appropriate to match the gender of those who will be using the system, or alternatively, to use gender to support a stereotype that the system might uphold. For example, for a matchmaker, users might expect to interact with a female agent, but an agent that matches the gender of the user might be more effective. If users have no clear mental model of what gender would best function in the role, such as a movie recommender, it creates a better opportunity to explore the power of gender in agent form.
2. “Casting” is a means of fleshing out agent personality. In casting (designing all aspects of, as in developing a character for fiction) an agent form, interaction designers need to consider whether to play into or play against a stereotype. What are the social and emotional undercurrents of the transactions taking place? Are they private, serious, entertaining, professional, etc.? These undercurrents influence the tone users expect and therefore the form they prefer. Gender stereotypes can have great influence on how users perceive an agent and how smoothly a transaction will take place. For example, a site providing information on housecleaning services may do best with a female maid stereotype. The choice of the agent will affect the overall tone of the transaction and will begin to reflect back on the user’s perception of the underlying product/service and the company that provides it. Gender, race, age, language and behavior can all be designed in coordination to support casting.
3. Recasting is a means for creating experiences within and across product use. In designing the interactions between embodied agents and people, interaction designers should look for opportunities to recast the agent’s visual form. Apple’s Guides interface offers a model where the agent’s visual form changed across the content [2]. Interaction designers should consider the content, the transition points within an agent’s tasks, and the social and cultural diversity of the users. Many agents perform a variety of tasks. In recasting, interaction designers might, for example, cluster tasks around different social roles. In this way, the agent can change

form as the tasks change, allowing it to best match the current transaction. Additionally, when opportunities arise where the system knows something about the user before an embodied agent is introduced, the system can select a form that best matches the social and cultural expectations of the specific user as opposed to having one form for all users.

8 Conclusion and Future Work

This paper presented two studies that explore the relationship between the visual features of embodied agents, the tasks these agents are intended to perform, and the social attributions that result. The first study looks at a representative set of agents that were found in research projects and industrial products. The second study employs agents we designed ourselves to explore whether these embodied agents, kept consistent except for minimal differences to suggest gender, produce the same effects we observed in the first study. Our results for both studies were similar. They show a clear link between agent task and form and reveal that men and women often prefer agent forms that conform to gender. We also provided a set of emerging design considerations to help guide interaction designers in creating the visual form of embodied agents.

Our future work will include exploring the notion of casting and recasting throughout a system featuring embodied agents, in order to understand how it might change the use of the underlying system. An additional next step will be to begin to explore how dynamic interaction elements, such as gaze and movement, support the findings for visual form of agents.

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