

Brains or Beauty: How to Engender Trust in User-Agent Interactions

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Software-based agents are becoming increasingly ubiquitous and automated. However, current technology and algorithms are still fallible, which considerably affects users' trust and interaction with such agents. In this paper, we investigate two factors which can engender user trust in agents: reliability and attractiveness of agents. We show that it is not enough for agents to be simply reliable, they need to be attractive as well in order to encourage user interaction. Subjective user ratings of agent trust and perceived accuracy suggest that attractiveness may be even more important than reliability.

CCS Concepts: • **Human-centered computing** → **Web-based interaction; User centered design; Interaction design theory, concepts and paradigms;** • **Applied computing** → **Psychology; Sociology;**

Additional Key Words and Phrases: Intelligent personal assistants; software agents; trust; reliability; attractiveness; intelligent agents

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1. INTRODUCTION

Software agents or intelligent personal assistants are playing an increasingly prominent and ubiquitous role in our lives. Examples of such smart personal agents include Microsoft's Cortana [Cortana 2015], Apple's Siri [Siri 2015], or Google's Google Now [Google Now 2015]. Agents can collaborate with users or perform tasks on users' behalf autonomously, gradually becoming more effective as they learn the users' interests, habits and preferences [Maes 1994]. Maes [Maes 1994] states that two main problems need to be solved when building software agents: 1) *Competence*: decisions of when to help the user and what to help them with, and 2) *Trust*: how we can guarantee that the user will trust the agent in making those decisions.

Humans have been shown to have "algorithm aversion" where they show greater intolerance to an algorithmic error than a human error [Dietvorst et al. 2014]. While current artificial intelligence remains fallible, it is crucial that as researchers in user-agent interactions, we understand and develop the second problem area defined by [Maes 1994]: how to build and maintain trust in the human-computer relationship even when the system inevitably makes errors. Trust has been defined as "*an evolving, affective state including both cognitive and affective elements and emerges from the perceptions of competence and a positive, caring motivation in the relationship partner to be trusted*" [Young and Albaum 2002]. What is interesting about this definition is its intrinsic ties with user affect. This idea of trust containing both affective and cognitive

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elements was first introduced in the field of sociology [Lewis and Weigert 1985]. In the context of user-agent interactions, *affective trust* is related to the perception that an agent's actions are intrinsically motivated and is based on affect generated by care, concern, and security [Johnson-George and Swap 1982; Rempel et al. 1985]. *Cognitive trust* is based on rational thought processes and empirical evidence [Lewis and Weigert 1985]. Cognitive trust is very closely related to an intelligent agent's competence as defined by [Maes 1994], whereas affective trust could be developed by ensuring and enhancing other factors in the agent.

In order to engender trust in intelligent agents, researchers have been turning to paradigms developed in social psychology that investigate human-to-human relationships and applying them to human-computer interaction [Reeves and Nass 1996; Bickmore and Picard 2005]. A very well established paradigm is that of the physical attractiveness stereotype where people attribute other positive personality traits onto attractive people [Dion et al. 1972]. A correlation between physical attractiveness and trustworthiness has been shown across several fields. Perhaps most interestingly, it has been demonstrated in acts of transgression or breaches of trust. Adults view more attractive children's transgressions less negatively and view less attractive children's offenses as more of an enduring dispositional fault [Dion 1972]. Mock juror studies show that physically attractive defendants are found to be guilty less often and are given shorter sentences [Efran 1974; Mazzella and Feingold 1994]. Studies of judicial decisions in real courtrooms show that attractiveness is highly predictive of both minimum and maximum sentences [Stewart 1980; 1985] and that judges exhibited a strong attractiveness-bias in the bails and fines that they set [Downs and Lyons 1991].

As software agents will become increasingly embodied in the future, it seems unlikely that unattractive intelligent personal assistants will become the norm. However, in this paper, we investigate whether we could leverage the power of the physical attractiveness stereotype to cope with deficiencies in the machine. We investigate the effects of reliability and attractiveness of embodied agents on users' trust.

2. RELATED WORK

2.1. Trust between Humans and Computers

Research on trust between humans and intelligent systems can be divided into two broad categories: 1) *The algorithms of the decision making* - i.e., the *what* and *when* of the system's adaptations, and 2) *The interaction style and design* - i.e., *how* the system interacts with the user.

These two categories can be linked to the two categories defined in cognitive and affective trust. Trust in algorithmic decision making, i.e., the artificial intelligence of the system-based agent, is akin to cognitive trust, whereby trust is based on rational-thinking. However, current artificial intelligence technology is fallible. While errors still exist in intelligent systems, as user-agent interaction researchers, we can draw from the power of the second category, the interaction style and design, to cope with deficiencies in the machine. In other words, we could build affective trust in system-based agents by designing the system in way that will engender user trust, even if some mistakes are made. We discuss the two categories in further detail below.

2.1.1. Trust and the Decision Making Algorithms. The importance of the adaptations made by the system can determine whether the intelligent system should be entrusted to intervene and what actions it should take [Dabbish and Baker 2003]. Transparency of such algorithms behind the system's decisions, knowledge of the system's resources, [Glass et al. 2008] and inclusion of comprehensive product information [Lee et al. 2000] have been found to be important to engendering trust with the user. Not only do users want to understand the decision making processes, but they also would like mecha-

nisms to override erroneous behavior when necessary [Glass et al. 2008]. They also are much more reluctant to trust intelligent systems to make important changes such as making a purchase with a credit card [Glass et al. 2008].

System reliability is crucial to building trust between the human and computer and needs to be built early on [Maltz and Meyer 2000; LeeTiernan et al. 2001]. Maltz and Meyer [Maltz and Meyer 2000] provided users carrying out a visual task with potentially helpful cues that varied in their reliability. They found that only the users who received highly reliable cues in the first set of trials continued to accept suggestions in the second set of trials. LeeTiernan et al. [LeeTiernan et al. 2001] found that when users' first impression of system reliability was high, they continued to use system suggestions, even when reliability decreased. Conversely, when first impressions denoted low system reliability, users would not accept system suggestions even when reliability increased [LeeTiernan et al. 2001]. Similarly, when users viewed an algorithmic error in a forecasting system, they lost confidence in the system and chose an inferior human forecaster over it [Dietvorst et al. 2014].

2.1.2. Trust and the Interaction Style and Design. HCI researchers have been taking paradigms in social psychology used in human to human relationships and applying them to develop human to computer relationships [Reeves and Nass 1996; Bickmore and Picard 2005]. Transfer of results has been found using these paradigms as people do demonstrate anthropomorphic behavior towards computers [Nass and Moon 2000]. Behaviours include applying human social categories such as gender and ethnicity to computers or engaging in social behaviors such as politeness and reciprocity [Reeves and Nass 1996; Nass and Moon 2000].

Social psychology has shown that humans are persuaded through association with good feelings [Galizio and Hendrick 1972; Schwarz et al. 1991; Mackie and Worth 1991] and that they like people more who like them [Kenny and Nasby 1980]. So it is not surprising that flattery can be a powerful tool to increase likability [Berscheid and Hatfield 1969]. For example, Fogg and Nass [Fogg and Nass 1997] found that humans are susceptible to flattery from computers and that the effects are the same as flattery from humans. Participants subjected to flattery reported greater performance and more positive evaluations of the human-computer interaction [Fogg and Nass 1997]. Lee [Lee 2008] also found flattery increased positive impressions of the computer, however, flattery was also found to increase user suspicion about the validity of computer feedback and actually lowered acceptance of computer suggestions. A suggested explanation for this has been that flattery temporarily fosters mindfulness, thus making users scrutinize the available information [Lee 2009].

The similarity or familiarity paradigm in social psychology has demonstrated that people will like others who are similar to them [Griffitt and Veitch 1974; Kandel 1978]. Users prefer computers that match them in personality over those that do not [Reeves and Nass 1996]. Interestingly, users actually prefer computers that become more like them over time more than computers that maintain a consistent level of similarity [Reeves and Nass 1996].

Other relational behaviors used in human relationships have been adopted by HCI researchers. Virtual agents that use humor are rated as being more likable, competent and cooperative [Morkes et al. 1998]. Computers that engage in reciprocal and deepening self-disclosure during conversation engender more personal information from the user and increase chances of a product sale [Moon 1998]. Highly expressive pedagogical agents increase students' perception of trust [Lester et al. 1997]. Bickmore and Picard [Bickmore and Picard 2005] found that a relational embodied agent that used social dialogue, meta-relational dialogue, politeness, non-verbal empathy exchanges,

and continuity behaviors was trusted, respected and liked more than a non-relational agent.

Another human trait that has been investigated is the physical attractiveness stereotype, which is a long-held paradigm in social psychology stemming from “what is beautiful is good”, whereby people attribute other positive traits onto attractive people [Dion et al. 1972]. We will now discuss it in further detail.

2.2. Physical Attractiveness Stereotype

The unfortunate and uncomfortable truth is that, as human beings, we are positively biased towards physically attractive people. Physically attractive people are thought to possess more favorable characteristics such as being more sociable, happier, sexually warmer [Miller 1970; Dion et al. 1972; Alley and Hildebrandt 1988], better adjusted and more self-assertive [Eagly et al. 1991], more intelligent [Jackson et al. 1995], more successful in life [Dion et al. 1972; Nida and Williams 1977], be better marital partners [Nida and Williams 1977], have greater social power [Mills and Aronson 1965; Sigall et al. 1969], have more positive effects on other people and receive more positive responses from others including requests for help and requests at work [McGuire 1969], more persuasive [Baker and Churchill Jr 1977; Dion and Stein 1978; Chaiken 1979], and more qualified for jobs [Hosoda et al. 2003] than less physically attractive people.

The physical attractiveness stereotype has held up consistently across different populations, and exists in older, more sophisticated groups such as health professionals [Nordholm 1980], teachers [Elovitz and Salvia 1983] and other professional groups [Alley and Hildebrandt 1988]. The stereotype also holds in young children who are biased towards more attractive children [Dion 1973; Dion and Berscheid 1974; Langlois and Stephan 1981]. Even 3-month-old infants show selective preference for attractive over unattractive adult faces [Langlois et al. 1987; Samuels and Ewy 1985], suggesting that attractiveness standards are more inherently acquired.

While two reviews have found the physical attractiveness stereotype is stronger for certain personality traits, with less correlation across integrity of character and attractiveness [Eagly et al. 1991; Feingold 1992], there is a wealth of evidence across many fields to suggest that there is certainly some favorable bias in the area of trustworthiness and physical attractiveness. Patzer [Patzer 1983] found that communicators with higher levels of physical attractiveness were perceived as more trustworthy and of higher expertise than communicators of lower physical attractiveness. Higher communicator physical attractiveness also had a significant effect for increased liking of the communicator [Patzer 1983]. This ties in with findings that celebrities who are liked will also be trusted [Friedman et al. 1978]. Friedman and Friedman [Friedman and Friedman 1976] found a significant correlation between physical attractiveness and trustworthiness of political figures.

This correlation between physical attractiveness and trustworthiness carries into breaches of trust as well. Adults view more attractive children’s transgressions less negatively. Moreover, when the child is unattractive, the offense is seen to be more of an enduring dispositional fault [Dion 1972].

This bias translates into later life where mock juror studies show that physically attractive defendants are treated more leniently than unattractive defendants for many types of crimes such as robbery, rape, cheating, and negligent homicide [Efran 1974; Sigall and Ostrove 1975; Mazzella and Feingold 1994]. Physically attractive defendants are found to be guilty less often and are given shorter sentences [Efran 1974; Mazzella and Feingold 1994]. This has not been found to be the case for the crime of swindling where the crime is attractiveness-related [Sigall and Ostrove 1975; Mazzella and Feingold 1994]. While Mazzella and Feingold [Mazzella and Feingold 1994] suggest that such results are linked to defendant likability in that attractiveness may

be promoting liking, Abwender and Hough [Abwender and Hough 2001] controlled for likability and found unchanged results, suggesting that jurors are responding to something more than just likability.

The correlation between defendant physical attractiveness is also externally valid as corroborated by length of sentencing in real courtrooms by judges and juries. Stewart [Stewart 1980] found that attractiveness was highly predictive of both minimum and maximum sentences, with the more attractive the defendant, the less serious the sentence imposed. These findings were confirmed by Stewart [Stewart 1985] and were found to remain significantly correlated even when the seriousness of the crime was controlled. Downs and Lyons [Downs and Lyons 1991] investigated judges' sentencing of 915 female and 1,320 male defendants who were unable to alter their appearance levels prior to court appearances. They found, once again, that judges exhibited a strong attractiveness-bias in the bails and fines that they set (for misdemeanor charges) [Downs and Lyons 1991].

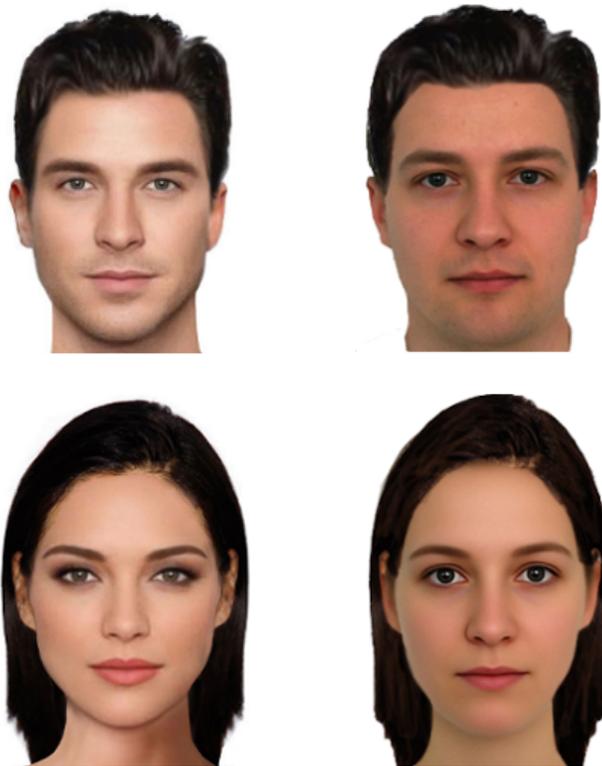


Fig. 1. Highly attractive agents (left) courtesy of Dr. Stuart Gibson and Dr. Chris Solomon, University of Kent. Neutrally attractive agents (right) courtesy of Dr. Martin Gruendl, Beautycheck.

3. HYPOTHESIS

In this paper we investigate two factors that affect trust: agent reliability and agent attractiveness. We test the following hypothesis:

Hypothesis: Reliability is more important than attractiveness in building trust in user-agent interactions.

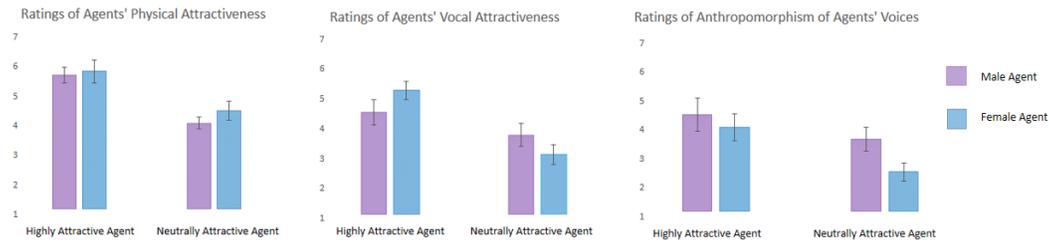


Fig. 2. Mean and standard error of participants' ratings of the highly and neutrally attractive agents' *left*: physical attractiveness, *center*: vocal attractiveness, and *right*: vocal human-likeness.

4. METHOD

4.1. Materials

We chose to test highly attractive vs. neutrally attractive agents and avoid the unattractive condition as it would be highly unlikely that system designers would purposefully create unattractive agents. We prepared the material for agency appearance and voice accordingly.

4.1.1. Attractiveness of Physical Appearance. Research has shown that certain facial features are optimized for attractiveness, such as when the distance between the eyes and mouth is 36% of the face's length, or when the distance between the eyes is 46% of the face's width [Pallett et al. 2010]. A large increase in the distance between the eyes and mouth is perceived as grotesque [Searcy and Bartlett 1996]. The eyes and mouth have consistently been the specific facial regions found to be most influential for facial attractiveness ratings [Alley and Hildebrandt 1988].

We turned to two external sources that have worked in the area of facial features and attractiveness who kindly gave us their permission to use faces that they had already synthesized.

The two attractive agents' faces were provided courtesy of Dr. Stuart Gibson and Dr. Chris Solomon from the University of Kent. They created the faces as archetypal models of beauty from externally rated features of beauty by 100 people in the United Kingdom. Important features of beauty included distance between the eyes, nose length and width, thickness of lips and width of mouth. Figure 1 shows the highly attractive agents on the left.

The two neutrally attractive agents' faces were provided courtesy of Dr. Martin Gruendl at Beautycheck. The neutral female is averaged from 64 female faces. We were going to use a male face averaged together from male faces however the averaged male face was externally rated as more attractive (Dr. Martin Gruendl, Beautycheck) than the averaged female face, therefore we went with a more neutral looking male face. Figure 1 shows the neutrally attractive agents on the right.

We transplanted the same hair onto both the attractive and neutral faces as pilot studies showed that participants' ratings of agent attractiveness was being affected by differences in hair (Figure 1).

We then ran our own preliminary study to verify the attractiveness of the agents. We asked 20 participants (11 female) to rate the physical attractiveness of the agents on a scale of 1-7 with 1 being 'Very Unattractive' and 7 being 'Very Attractive'. Participants rated their main gender of sexual preference (all participants were heterosexual so they rated the opposite gender's physical attractiveness). Figure 2 shows that participants rated the agents that were designed to be more physically attractive higher than those designed to be neutrally attractive.

4.1.2. *Attractiveness of Voice.* Vocal attractiveness has been shown to increase the attractiveness of face plus voice agency [Zuckerman and Driver 1989], it was therefore important that we maintained a differentiation of attractiveness in the vocalization of the agents. A stereotype for vocal attractiveness has been shown [Zuckerman and Driver 1989; Zuckerman et al. 1990] where attractive voices are rated more favorably in voice only and face plus voice conditions.

Studies from biological psychology have shown that men seem to prefer women with higher pitched voices which is associated with smaller body size [Liu and Xu 2011], and women actually speak in a higher pitched to men they find attractive [Fraccaro et al. 2011]. Conversely, women seem to find men with lower pitched voices more attractive [Collins 2000; Apicella et al. 2007] as this seems to indicate larger body size and other masculine traits [Evans et al. 2006].

We used these findings when building the voices of our agents using an internal Microsoft text to speech toolkit software. The female attractive voice was higher in pitch than the female neutral voice. The male attractive voice was lower in pitch than the male neutral voice. Furthermore, both the male and female attractive voices had prosodic contours with slight rises and falls in pitch, emphasis in places, and slight changes in the rhythm of speech. The neutral voices simply had a neutral tone throughout.

We asked 21 participants (11 female) to rate the vocal attractiveness of the voices on a scale of 1-7 with 1 being 'Very Unattractive' and 7 being 'Very Attractive'. Participants rated their main gender of sexual preference (all participants were heterosexual so they rated the opposite genders voices). Figure 2 shows that participants rated the voices that were designed to be more attractive higher than those designed to be neutrally attractive.

Due to the differences in prosodic contours creating more human-like speech patterns, we also asked participants to rate how human-like vs. machine-like the voices sounded, with 1 denoting 'Very Machine-Like' and 7 being 'Very Human-Like'. Figure 2 shows that participants thought that the neutral voices sounded more machine-like than the attractive voices. It is possible therefore, that this factor affects participants' preferences, which we consider when evaluating the results.

4.2. Experimental Design

Participants took part in a within-subject 2 (high vs. low reliability) x 2 (high vs. neutral attractiveness) agency design. Participants answered four sets of 15 questions. Each set had one of the four conditions:

- A highly reliable and highly attractive agent (Reliable_{HIGH} Attractive_{HIGH}).
- A highly reliable and neutrally attractive agent (Reliable_{HIGH} Attractive_{NEUTRAL}).
- A lesser reliable and highly attractive agent (Reliable_{LOW} Attractive_{HIGH}).
- A lesser reliable and neutrally attractive agent (Reliable_{LOW} Attractive_{NEUTRAL})

The ordering of the conditions was alternated so that there was a fair distribution. We controlled for agents to be participants' main gender of sexual preference. All participants reported to be heterosexual and therefore only interacted with agents of the opposite gender.

In the high reliability conditions, 5 out of the six suggestions offered by the agent were correct. In the low reliability conditions, 3 out of the six suggestions offered by the agent were correct. The percentages for high and low

Question 1 of 15

Q1: Which of these words is spelled and pronounced the same way in English as it is in Spanish, German, Thai, Chinese, and Farsi?

no

taxi

police

visa

Submit Answer

Time remaining for this question: 00:34 seconds!

Question 2 of 15

Q2: Besides a protrusion sticking out of a feline's face, a 'cat's whisker' is also a type of:

antenna

guitar string

surgical stitch

skewer

Submit Answer

Time remaining for this question: 00:23 seconds!

Tell me the answer

Fig. 3. Top: Example of question without a suggestion. The time remaining can be seen on the bottom-left. Bottom: Example of a question with an agent offering a suggestion. Participants would hear the agent offering a suggestion as well. If they wished, the participant could hear the suggestion by pressing on the ‘Tell me the answer’ button.

reliability (80% and 50% respectively) were taken from user trust literature [LeeTiernan et al. 2001]. The order of the correct and incorrect answers were randomized on each trial.

Question 1 of 15

Q1: Which of these words is spelled and pronounced the same way in English as it is in Spanish, German, Thai, Chinese, and Farsi?

Incorrect. The answer is taxi. You have -1 out of 1 correct.

no

taxi

police

visa

Submit Answer

Question 1 of 15

Q1: Which of these words is spelled and pronounced the same way in English as it is in Spanish, German, Thai, Chinese, and Farsi?

Correct! The answer is taxi. You have 0 out of 1 correct.

no

taxi

police

visa

Submit Answer

Fig. 4. Examples of feedback for an incorrect (left) and correct (right) answer. Participants gained a point for every correct answer, and lost a point for every incorrect answer and every time they timed out in order to discourage guesswork.

The questions were multiple-choice and were general knowledge. Questions were on a broad range of topics and were designed to a difficulty level that required searching on most questions for most participants [Hyperion 2000; Wood and Kovalchik 2012]. Examples are included in Figure 3. Participants could search for the answers in a search engine on a separate monitor. They had 40 seconds to answer each question and they could see how much time they had left for each question with a countdown showing on the screen (Figure 3). For every question they answered correctly, they would gain a point, and they could move onto the next question. If they answered a question incorrectly they would lose a point (to discourage guesswork) and would have to keep attempting the question until they got the right answer or timed-out. If they timed-out they would also lose a point. They received a 2 minute break in between each set of questions. Participants were incentivized to reach high scores in the questions with extra gratuity. Participants always received immediate feedback when they answered a question (Figure 4).

Participants were told that every now and then an agent would appear on the screen to help them with the answer to a question. They were told that the agents would offer a suggestion for the answer and that they could click on the *'Tell me the answer'* button to hear the suggestion (Figure 3). Before starting the experiment, participants were introduced to the two agents (highly and neutrally attractive) of their gender of preference from Figure 1.

For each set of 15 questions, 6 questions were picked pseudo-randomly on each trial to have suggestions. The suggestions were spread out so that the first five questions had 2 suggestions, the second five questions had 2 suggestions, and the last five questions had 2 suggestions.

4.2.1. Participants. Twenty participants took part in the study. One participant had to be excluded from the data set as they did not follow the instructions. Out of the remaining 19 (11 female), there was a wide range in ages: 17-51 years ($\mu = 30, \sigma = 11.24$). Ten participants were recruited internally from Microsoft Research, nine were recruited externally from the general public. Participants received a gift certificate for their participation. They were also offered an additional incentive of a \$25 Amazon gift card if they could achieve 75% accuracy or higher in one of the sets of questions.

5. MAPPING OF DEPENDENT VARIABLES TO TRUST

Trust is a complex issue, and measuring it is no less simple. In this section, we present a mapping of how each dependent variable relates to the topic of trust in user-agent interactions.

Number of Questions With Button Presses

Users could choose to hear an agent's suggestion by pressing the "Tell me the answer" button. We analyzed the number of questions with button presses to verify how often users opted to hear agents' suggestions. This is different from the number of button presses in total because in some trials users pressed the button more than once to re-listen to the suggestion for clarification or reminder purposes. There was no cost to listening to agent suggestions.

This measure also acts as verification that users are not being exposed to skewed feedback from different conditions.

Self-reported Measures of Trust in Agent

This measure users' trust in the agents.

Self-reported Measures of Perceived Accuracy of Agent

This measured users' perceived accuracy of agents. This reveals whether perceived

agent reliability can be affected by other factors such as attractiveness, hence indicating where trust is being directed.

Number of Correct Suggestions Accepted

Due to the difference in the correct answers supplied by the agents with high versus low reliability, this measure should show this difference. A difference in the number of accepted correct answers between the high and low reliable agents will indicate a difference in trust between agents. Each correct answer gained the user a point.

This measure also acts as verification that users are not being exposed to skewed feedback from different conditions.

Number of Incorrect Suggestions Accepted

Similarly, this measure should show a difference between agents with high and low reliability due to the difference in incorrect answers supplied by those two groups of agents. A difference in the number of accepted correct answers between the high and low reliable agents will indicate a difference in trust between agents. This measure is different from number of correct suggestions accepted as users can select more than one incorrect answer for each question. Each incorrect answer cost the user a point.

This measure also acts as verification that users are not being exposed to skewed feedback from different conditions.

Length of Time Spent on Questions With Suggestions

This measure indicates trust by whether a user will accept the agent's suggestion or verify the answer with an Internet search. For the agents with high reliability, generally the longer the time taken, the less trust in the agent. However, due to agents with less reliability offering a greater number of incorrect suggestions, greater time spent may indicate that users were accepting incorrect suggestions, which is still indicative of trust. Therefore this measure is best compared between the agents with high and low reliability.

Number of Timeouts With Suggestions

Each question timed-out after 40 seconds, costing the user a point. Therefore, if a user timed-out on a question where an agent was offering a suggestion, this suggests a lack of trust. This is true across all conditions.

Number of Correct Answers

Agents with higher reliability offered a higher percentage of correct answers. Therefore this measure should show a difference between the agents with high and low reliability. A deviation from this would indicate a difference in trust between agents with high and low reliability.

This measure also acts as verification that users are not being exposed to skewed feedback from different conditions.

Number of Incorrect Answers

This measure should show an even greater difference between the agents with high and low reliability due to the fact that users can submit multiple incorrect answers per question. Therefore, questions with suggestions from an agent with low reliability can result in several incorrect answers.

This measure also acts as verification that users are not being exposed to skewed feedback from different conditions.

6. RESULTS

6.1. Verification of Attractiveness Independent Variable

We first examined participants' ratings for the attractiveness of the agent's appearance and voice in order to verify the independent variables of attractiveness. Participants

rated agents' physical and vocal attractiveness on two separate scales of 1-7 with 1 being 'Very Unattractive' and 7 denoting 'Very Attractive'.

6.1.1. Attractiveness of Physical Appearance. A paired t-test showed extremely significant different responses in participants' ratings of agents' physical attractiveness ($t(37) = 2.03, p = .00005$). Participants rated the agents designed to be highly attractive ($\mu = 4.8, \sigma = 0.8$) as significantly more physically attractive than the agents designed to be neutrally attractive ($\mu = 3.9, \sigma = 1.1$).

6.1.2. Attractiveness of Voice. A paired t-test also showed significant results for participants' ratings of agents' vocal attractiveness ($t(37) = 2.03, p = .02$). Participants rated the voices designed to be highly attractive ($\mu = 4.3, \sigma = 1.3$) as significantly more attractive than the voices designed to be neutrally attractive ($\mu = 3.9, \sigma = 1.2$).

These findings may be due, at least partially, to participants responding to the more human-like quality of the more attractive voices, as rated during preliminary studies of agents' voices (Figure 2).

6.2. Dependent Variables

6.2.1. Questionnaire Results on Trust and Accuracy. We carried out various 2 (high vs. low reliability) x 2 (high vs. neutral attractiveness) repeated measures (RM) ANOVAs with a Greenhouse-Geisser correction across all dependent variables. For all significant results we calculated post-hoc analyses using Bonferroni corrections.

Results on *self-reported ratings of agent trust* showed a significant difference for the attractive agents ($F(1, 18) = 11.473, p = .003, \eta^2 = .389$) (Table I). Post-hoc analysis revealed that users trusted the $\text{Reliable}_{\text{HIGH}} \text{Attractive}_{\text{HIGH}}$ agent significantly more than both of the neutrally attractive agents (including the $\text{Reliable}_{\text{HIGH}} \text{Attractive}_{\text{NEUTRAL}}$ ($p = .011$) and $\text{Reliable}_{\text{LOW}} \text{Attractive}_{\text{NEUTRAL}}$ ($p = .005$) agents). Interestingly, there was no significant difference between the $\text{Reliable}_{\text{LOW}} \text{Attractive}_{\text{HIGH}}$ agent and the highly reliable agents (Figure 5) (while Likert scales of 1-7 were given to participants with 1 denoting a low value and 7 denoting a high value, graphs show a scale of 0-6 to show better differences between conditions).

Results also showed *users' self-reporting of agent accuracy* was significantly different for more attractive agents ($F(1, 18) = 26.645, p < 0.001, \eta^2 = .510$) (Table I). Post-hoc analysis showed that users thought both of the highly attractive agents were more accurate than the $\text{Reliable}_{\text{HIGH}} \text{Attractive}_{\text{NEUTRAL}}$ agent. Both the $\text{Reliable}_{\text{HIGH}} \text{Attractive}_{\text{HIGH}}$ agent ($p = .005$) and even the $\text{Reliable}_{\text{LOW}} \text{Attractive}_{\text{HIGH}}$ agent ($p = .006$) were significantly more accurate than the $\text{Reliable}_{\text{HIGH}} \text{Attractive}_{\text{NEUTRAL}}$ agent (Figure 5).

These results indicate that attractiveness is more important than reliability for user perceptions of trust and accuracy. We turn to data gathered from user-agent interaction to investigate these findings further.

6.2.2. User-Agent Interactions. There was a significant difference in the *number of correct suggestions accepted* for the reliability variable ($F(1, 18) = 25.352, p < 0.001, \eta^2 = .585$) and the interaction between reliability and attractiveness ($F(1, 18) = 4.569, p = .047$) (Table I). As expected, post-hoc analysis showed that users accepted a significantly higher number of correct suggestions from the $\text{Reliable}_{\text{HIGH}} \text{Attractive}_{\text{HIGH}}$ agent than for the lower reliability agents, regardless of attractiveness ($p < 0.001$). This was expected as the highly reliable agents provided a higher number of correct suggestions in the first place than the agents with lesser reliability.

However, we did not expect for there to be *no significance* between the $\text{Reliable}_{\text{HIGH}} \text{Attractive}_{\text{NEUTRAL}}$ agent and the lower reliability agents (Figure 5). This occurred

Table I. Results of 2x2 RM-ANOVAS on agent reliability and attractiveness

Dependent Variable	Factor	F-value	p-value	η^2
Number of Questions With Button Presses	Reliability	3.485	.078	.162
Number of Questions With Button Presses	Attractiveness	3.547	.076	.165
Number of Questions With Button Presses	Interaction	4.455	.049	.198
Questionnaire on Trust	Reliability	0.548	.469	.030
Questionnaire on Trust	Attractiveness	9.642	.006	.389
Questionnaire on Trust	Interaction	0.986	.334	.052
Questionnaire on Accuracy	Reliability	1.536	.231	.079
Questionnaire on Accuracy	Attractiveness	18.731	<.001	.510
Questionnaire on Accuracy	Interaction	0.706	.412	.038
Number of Correct Suggestions Accepted	Reliability	25.352	<.001	.585
Number of Correct Suggestions Accepted	Attractiveness	3.888	.064	.178
Number of Correct Suggestions Accepted	Interaction	4.569	.047	.202
Number of Incorrect Suggestions Accepted	Reliability	65.681	<.001	.785
Number of Incorrect Suggestions Accepted	Attractiveness	0.029	.867	.002
Number of Incorrect Suggestions Accepted	Interaction	0.073	.790	.004
Time Spent on Questions With Suggestions	Reliability	13.027	.002	.420
Time Spent on Questions With Suggestions	Attractiveness	6.321	.022	.260
Time Spent on Questions With Suggestions	Interaction	0.073	.790	.004
Number of Timeouts With Suggestions	Reliability	6.892	.017	.277
Number of Timeouts With Suggestions	Attractiveness	1.000	.331	.053
Number of Timeouts With Suggestions	Interaction	.053	.821	.003
Number of Correct Answers	Reliability	3.512	.077	.163
Number of Correct Answers	Attractiveness	3.337	.084	.156
Number of Correct Answers	Interaction	.476	.499	.026
Number of Incorrect Answers	Reliability	5.773	.027	.243
Number of Incorrect Answers	Attractiveness	0.585	.454	.031
Number of Incorrect Answers	Interaction	.249	.624	.014

Note: All dependent variables that remained significant *after* the Bonferroni correction are highlighted in bold. All results have a df of (1,18).

even though the agents with lower reliability had many fewer correct suggestions to offer.

There was also a significant difference in the *number of incorrect suggestions accepted* for the reliability variable ($F(1, 18) = 65.681, p < 0.001, \eta^2 = .785$) (Table I) as expected.

Results for the *time spent on questions when the agent offered suggestions* showed that there was a significant difference in both reliability ($F(1, 18) = 13.027, p = .002, \eta^2 = .420$) and attractiveness ($F(1, 18) = 6.321, p = .022, \eta^2 = .260$) (Table I). Post-hoc analysis revealed that users spent significantly less time on questions with the Reliable_{HIGH} Attractive_{HIGH} agent than the Reliable_{LOW} Attractive_{NEUTRAL} ($p = .003$) agent (Figure 5). Interestingly, once again there were no significant difference between the Reliable_{HIGH} Attractive_{NEUTRAL} agent and the low reliability agents. There were also no significant differences between the Reliable_{LOW} Attractive_{HIGH} agent and the highly reliability agents (Figure 5).

We used the median when measuring time as is standard practice when looking at reaction time distributions due to its robustness to skewness in the data. Figure 5 shows the mean of the medians.

There was a significant difference in the *number of incorrect answers* in reliability ($F(1, 18) = 5.773, p = .027, \eta^2 = .243$) (Table I) as expected due to the difference in incorrect suggestions offered between agents with high and low reliability.

However, there were no significant differences in the *number of correct answers* across conditions (Table I).

There were also no significant differences in the *number of questions with button presses* (indicating the number of times users asked to hear the suggestion from the

agent) (Table I) which is not surprising considering there was no cost or penalty associated with hearing the suggestion. There were also no differences in the *number of timeouts in questions with suggestions* (Table I).

We also examined all dependent variables for gender differences with 2x2x2 RM-ANOVAs and found ***no differences in gender*** throughout the results.

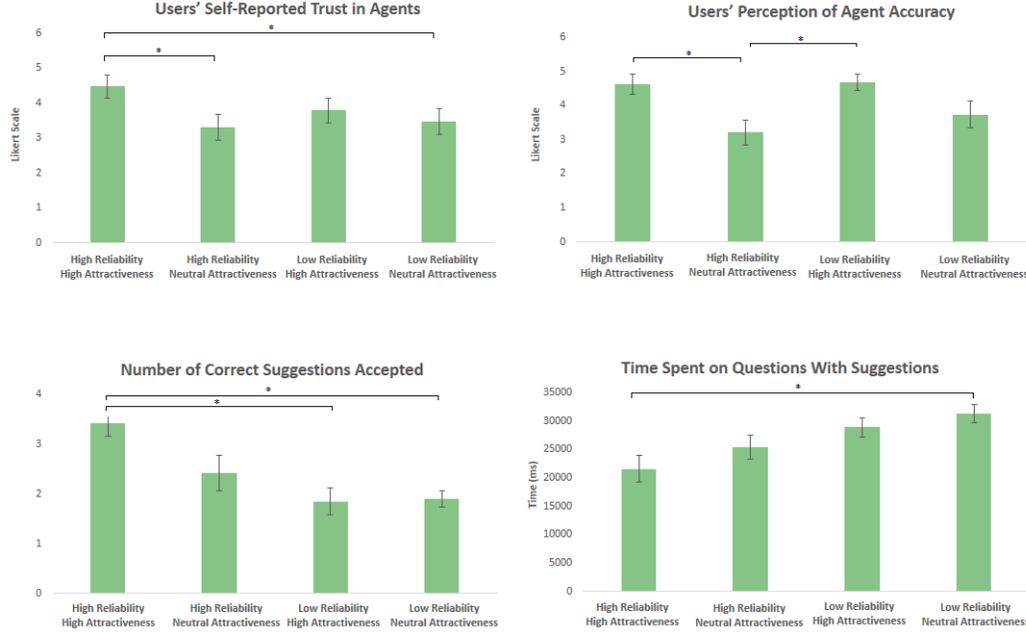


Fig. 5. Mean and standard error of users' self-reported trust in agents (top-left), user perception of agent accuracy (top-right), number of correct suggestions accepted (bottom-left), and time spent on questions with suggestions (bottom-right). Significant differences are indicated by an asterisk. Results indicate significant differences based on attractiveness in users trust in agents ($F(1, 18) = 11.473, p = .003$) and user perception of agent accuracy ($p = .005$ and $p = .006$). Contradictory to expectations, there were no significant differences between the Reliable_{HIGH} Attractive_{NEUTRAL} agent and the low reliability agents in either the number of correct suggestions accepted nor in the time spent on questions with suggestions.

7. DISCUSSION

7.1. Reliability Manipulation Check

Users seem to trust agents with high attractiveness more and think that they are more accurate. We first verify that these results were not due to skewed exposure from different agents, by examining the dependent variables.

7.1.1. Number of Button Presses. There was no significant difference in the number of button presses to hear agents' suggestions between conditions (Table I). Therefore users saw and heard the same number of suggestions across all conditions.

7.1.2. Number of Correct Suggestions Accepted. There was no significant difference in the number of correct suggestions accepted between the low reliability agents and the Reliable_{HIGH} Attractive_{NEUTRAL} agent (Figure 5). Therefore differences in data between those three agents is not due to a skew in exposure to correct answers being accepted.

7.1.3. *Number of Incorrect Suggestions Accepted.* There was a significant difference in the number of incorrect suggestions accepted between the high and low reliability agents (Table I) which was expected due to the higher number of incorrect suggestions provided by low reliability agents. Therefore any differences between highly and neutrally attractive agents were not due to skewed feedback in incorrect suggestions.

7.1.4. *Number of Correct Answers.* There was no significant difference in the number of correct answers across conditions, which once again verifies that the findings were not due to skewed exposure.

7.1.5. *Number of Incorrect Answers.* There was a significant difference in the number of incorrect answers between the high and low reliability agents (Table I) which was to be expected due to higher number of incorrect suggestions in the low reliability agents. Therefore any differences between highly and neutrally attractive agents were not due to skewed feedback in incorrect answers.

It seems, therefore, that the results are due to users' own reactions to and perceptions of the agents. We now examine the data in terms of the hypotheses stated at the start.

7.2. Is Reliability More Important than Attractiveness in Building Trust in User-Agent Interactions?

We now address the hypothesis:

Reliability is more important than attractiveness in building trust in user-agent interactions.

Interestingly, results suggest a rejection of this hypothesis. Questionnaire data indicated users trusted the Reliable_{HIGH} Attractive_{HIGH} agent significantly more than the Reliable_{HIGH} Attractive_{NEUTRAL} agent. Users also found the Reliable_{HIGH} Attractive_{HIGH} agent to be significantly more accurate than the Reliable_{HIGH} Attractive_{NEUTRAL} agent. This subjective evaluation of agents from users sheds light on how important agent attractiveness is in user-human interactions and relationships.

Objective user-agent interaction data showed us that the Reliable_{HIGH} Attractive_{NEUTRAL} agent was not treated differently from the agents with low reliability (Figure 5). While there were significant differences between the Reliable_{HIGH} Attractive_{HIGH} agent and the agents with low reliability in the number of correct suggestions accepted, there were no such significant differences between the Reliable_{HIGH} Attractive_{NEUTRAL} agent and the agents with low reliability. This was unusual because we had been expecting a significant difference in the number of correct suggestions accepted between the high and low reliability agents because the agents with lower reliability had fewer correct suggestions to offer.

This interaction data strongly suggests that users trusted the Reliable_{HIGH} Attractive_{NEUTRAL} agent less than the Reliable_{HIGH} Attractive_{HIGH} agent by accepting fewer of their correct suggestions. It is also very interesting that users accepted the same number of correct suggestions from the agents with lower reliability as the Reliable_{HIGH} Attractive_{NEUTRAL} agent. Additionally, results showed that there was no significant difference in the length of time spent on questions between the Reliable_{LOW} Attractive_{HIGH} agent and the highly reliable agents. The time spent on considering answers reflects users' propensity to trust the agents' answers or to verify them by searching online. Together, these findings indicate a distinct lack of trust in user interactions with this highly reliable yet neutrally attractive agent. This result is really quite surprising and demonstrates how even a highly reliable agent's

suggestions can be ignored by users if it is not accompanied with high levels of physical attractiveness.

Results indicate that it is not enough for an agent to simply be reliable for a user to trust it. It seems that **a reliable agent also needs to be attractive in order to gain users' trust enough for usage** at least within the boundaries of our study. While attractiveness could be viewed as being just as important as reliability, the questionnaire data where users reported trusting attractive agents more and finding them more accurate suggests that it might even be more important than reliability.

These findings are representative of the complexity of human nature in interactions with software agents. They highlight the importance and value of acknowledging and exploring traits such as physical attractiveness. We recommend the leveraging of any trait that will help users trust software agents enough to engage with them, including physical attractiveness. This is not to deceive users, but instead, to encourage interaction. Otherwise, as demonstrated in these results, even highly reliable agents can be ignored by users.

7.3. Cognitive and Affective Trust

A possible explanation for greater user trust in the more attractive agents, even over the highly reliable but neutrally attractive agent, is the concept of affective trust over cognitive trust. Dowell et al. [2015] found that in the early phase of a relationship cycle in business (in the first 12 months), affective trust was especially important. In later, more mature phases of the relationship cycle (after the first 12 months), cognitive trust was a more important factor than before [Dowell et al. 2015].

When there is less substantive evidence to build trust upon, it is thought that trust is based upon the hope or expectation that the task will be fulfilled, therefore cognitive trust would be less influential early on [Dowell et al. 2015]. It is therefore possible that users were basing their trust on the agents in terms of how they felt about the agents (affective trust) which could have been influenced by the level of agent attractiveness. Lewis and Weigert [1985] suggest that the stronger the affective trust in relation to the cognitive trust, the less likely behavioral evidence to the contrary will weaken the relationship. This could have occurred with the agent with lesser reliability but higher attractiveness, and with the agent with high reliability but lesser attractiveness. If users had established an affective attitude towards them based on appearance, this could have created a blindness to evidence based agent reliability.

Affective trust has been modeled into two sub-categories by Dowell et al. [2015]: 1. *Relational trust*, which is related to the 'leap of faith' aspect of affective trust where faith is placed in the other individual that they will act in a trustworthy way, and 2. *Intuitive trust* which is based on moods and feelings about the other individual. Dowell et al. [2015] found that relational trust was particularly important in the early phase of a relationship. The physical attractiveness stereotype has shown that people often attribute other positive traits onto physically attractive people, which could lend itself to this 'leap of faith' category.

It is important to note, however, that trust is a *mixture* of feeling and rational thinking [Weigert 1981]. In any user-agent interaction, it is not possible to exclude one or the other from the analysis of trust. However, affective trust seems to play a more important role than cognitive trust in primary group relations whereas cognitive trust seems to play a greater in secondary group relations [Lewis and Weigert 1985]. Considering the deeply personal relationship most users have with their computers, it is foreseeable that an intelligent personal assistant or software agent will be included in the user's primary social group, thereby making the affective trust aspect of the relationship even more important. This would need to be investigated in a more long-term study of trust in user-agent interactions.

7.4. Physical versus Vocal Attractiveness in User-Agent Interactions

In this study, we examined attractiveness as a combination of both physical and vocal attractiveness. It is possible that the two factors had an enhancing effect on the other. For example, vocal attractiveness has been shown to increase the attractiveness of face plus voice agency [Zuckerman and Driver 1989]. A separate study needs to be carried out to differentiate between the effectiveness of the two agencies.

After the completion of the main experiment, we carried out a pilot study to this effect to investigate the impact of vocal attractiveness *only* on engendering trust in user-agent interactions. Four new participants (1 female) carried out the same experiment with only the agent's voice as stimuli. No visuals of the agents were presented.

Results showed no significant differences for any of the dependent variables across any conditions. The users also reported being so engrossed in the task that they could not tell a marked difference in the agents' voices. This was in contrast to previous findings where 10 participants who heard the agents' voices (also with no physical appearance) in an environment where they were not carrying out any tasks could clearly hear the differences in the voices (Figure 2).

These are preliminary results, however, which require further investigation to differentiate which agency factors elicit the attractiveness stereotype in humans.

7.5. Limitations

It may have been easier for users in our study to accept the agents because they were merely 2D graphical representations of a real person and therefore avoided problems related to the uncanny valley. Systems with embodied virtual agents are currently being created that are able to move, gesture and lip-sync quite accurately when interacting with users (e.g., [Wang et al. 2011]). Examining the effects of reliability and attractiveness on the development of trust when agents are animated with natural gestures, facial expressions, and voice intonations would allow for a huge increase in agency parameters. This would provide a much more complex framework on which to design and investigate agent attractiveness and its effects on user-agent interactions.

Our interactions with users were merely in the form of question/answer types of interactions. While we used search scenarios and motivated participants with money to take the tasks seriously, more real world, complex interaction between the user and the agent, when stakes are higher, would also be a ripe area for future exploration.

However, in this work we feel we have contributed to knowledge about agent design and its effects on humans, suggesting that attractiveness and reliability are both important considerations, and interact in ways that should be kept in mind in future user-agent interactions.

8. CONCLUSION

We investigated the effects of reliability and attractiveness on the development of trust in user-agent interactions. We found that we had to reject our hypothesis that reliability was more important than attractiveness. Users reported trusting the highly attractive agents more and found them to be subjectively more accurate, even over the more reliable but less attractive agent. User-agent interaction data from the same number of correct suggestions accepted and length of time spent on questions showed that the highly reliable yet neutrally attractive agent was treated in the same way as the agents with low reliability. In addition, this agent was treated significantly differently from the agent who was highly reliable *and* highly attractive.

These results demonstrate that agent reliability is not simply more important than agent attractiveness in developing trust in user-agent interactions. In fact, attractiveness is just as important as reliability, and perhaps more so. These findings may be

due to users having greater affective trust than cognitive trust in the highly attractive agents, especially as these were early-phase interactions when there is a less rational basis for trust.

We hope this paper demonstrates that reliability by itself should not be the only point of focus in developing intelligent software agents. There has been a wealth of research conducted in social psychology for several decades highlighting the power and importance of the physical attractiveness stereotype. There has been further research demonstrating that humans respond to computers as if they were humans. Our study suggests that the attractiveness stereotype will follow humans into the future with our relationships and interactions with intelligent virtual agents.

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