Research Article

Digital Chameleons

Automatic Assimilation of Nonverbal Gestures in Immersive Virtual Environments

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ABSTRACT—*Previous research demonstrated social influence resulting from mimicry (the* chameleon effect*); a confederate who mimicked participants was more highly regarded than a confederate who did not, despite the fact that participants did not explicitly notice the mimicry. In the current study, participants interacted with an embodied artificial intelligence agent in immersive virtual reality. The agent either mimicked a participant's head movements at a 4-s delay or utilized prerecorded movements of another participant as it verbally presented an argument. Mimicking agents were more persuasive and received more positive trait ratings than nonmimickers, despite participants' inability to explicitly detect the mimicry. These data are uniquely powerful because they demonstrate the ability to use automatic, indiscriminate mimicking (i.e., a computer algorithm blindly applied to all movements) to gain social influence. Furthermore, this is the first study to demonstrate social influence effects with a nonhuman, nonverbal mimicker.*

The purpose of the current work was to examine the possibilities and limits of social influence resulting from the *chameleon effect*, the tendency for mimickers to gain social influence (Chartrand & Bargh, 1999), in computer-mediated communication. In Chartrand and Bargh's Study 2, confederates in a conversation either mimicked certain nonverbal behaviors of participants during a conversation or interacted normally with participants. Results demonstrated that subjects showed a preference toward nonverbal chameleons over normal interactants in terms of likability and interaction smoothness. In the current study, we sought to demonstrate that the chameleon effect is uniquely powerful in collaborative virtual environments (CVEs) that constantly and unobtrusively collect information concerning interactants' nonverbal behavior.

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THE CHAMELEON EFFECT

The synchronization of nonverbal cues in dyadic and group interactions was first described by Kendon (1970) and LaFrance (1982; LaFrance & Broadbent, 1976). Synchronization in dyadic and group interactions has since been observed in many other forms, such as in accents and speech patterns (Cappella & Panalp, 1981), syntax (Levelt & Kelter, 1982), and general mood contagion (Neumann & Strack, 2000).

More recently, it was shown that participants judged confederate mimickers to be more likable than confederates who did not engage in mimicry (Chartrand & Bargh, 1999), and also that waiters who repeated their customers' orders received larger tips than waiters who did not repeat their customers' orders (van Baaren, Holland, Steenaert, & van Knippenberg, 2003). Mimicry also increases an individual's prosocial behavior toward other people in general and not only toward the mimicker (van Baaren, Holland, Kawakami, & van Knippenberg, 2004). Moreover, expectations of future interactions increase mimicry behavior (Lakin & Chartrand, 2003). This line of evidence supports the claim that both unintentional (automatic) and intentional mimicry facilitate and express social affiliation and that the process is bidirectional—mimicry facilitates affiliation and prosocial behavior, and affiliation goals increase mimicry (Lakin, Jefferis, Cheng, & Chartrand, 2003). Similarly, LaFrance (1979) demonstrated that the positive correlation between posture sharing and rapport persists across time.

COLLABORATIVE VIRTUAL ENVIRONMENTS

In CVEs (Bailenson, Beall, & Blascovich, 2002; Slater, Sadagic, Usoh, & Schroeder, 2000; Zhang & Furnas, 2002), interactants in remote physical locations see the verbal and nonverbal behaviors of one another rendered onto digital *avatars* (representations of people in virtual reality; Bailenson & Blascovich,

2004) in real time. In other words, unlike a video conference, which transmits an analog-like stream of visual information, a CVE measures exactly what an interactant is doing (e.g., moving, smiling, and talking) and then animates those behaviors onto a digital avatar. Social scientists have begun to employ CVEs to study social interaction (Blascovich et al., 2002; Loomis, Blascovich, & Beall, 1999).

Consider a conference in which three people interact in a CVE. Each, on a local computer system, has stored his or her own complete version of the virtual conference room, including all of the digital objects (virtual chairs, tables, etc.) and realistic-looking versions of the other interactants' avatars. The only information that needs to travel over the network is simple information about the movements of each interactant. All visual data are stored locally, and the CVE, unlike a videoconference, does not repeatedly transmit any visual information—only simple information concerning movements and actions.

A powerful consequence of using this type of system is enabling transformed social interaction (TSI; Bailenson & Beall, in press; Bailenson, Beall, Loomis, Blascovich, & Turk, 2004), the strategic decoupling of signals (about appearance and behavior) performed by one interactant from signals received by another interactant. In other words, via TSI, interactants can use strategic algorithms to transform their own behaviors toward other interactants. One of the most intuitive applications of TSI is nonverbal mimicry. CVEs necessarily archive extremely detailed records of all verbal and nonverbal behaviors, which become available to other interactants the instant in which those actions occur. In other words, in order to make the CVE function properly (i.e., show the behaviors of one interactant to the others), the system needs to collect all actions from all participants. Consequently, it is possible for an interactant seeking social influence to use simple algorithms to automatically mimic the behaviors of any number of other interactants. Furthermore, an interactant can render his or her avatar differently to each of the other interactants, such that the mimicry is rendered uniquely to each person. Because this information is all digital, the frequency (how many times during an interaction the behavior is mimicked), the thoroughness (how many types of gestures or movements are mimicked at once), and the intensity (whether the mimicry is an exact mirror or only an approximation of the original gesture) of the transformation can all be precisely and automatically regulated. For that reason, there is great potential for digital chameleons to be quite effective.

THE CURRENT STUDY

The goal of the current study was to extend understanding of the chameleon effect in two directions. First, we were interested in whether the positive social effects of automatic mimicry would occur even when the participant was fully aware that the conversational partner was an *embodied agent* (i.e., a humanlike digital representation controlled by a computer, not another person). Research by Reeves and Nass (1996) demonstrating that people treat computer interfaces as social actors suggests that the chameleon effect might transfer to nonhuman mimickers. Given the prevalence of embodied agents in on-line games and software applications (Yee, in press), it is important to understand how TSI can be applied to communication between human and nonhuman interactants. Second, we were interested in exploring whether a mimicry strategy relying on extremely subtle nonverbal cues, such as slight head movements alone, would be sufficient to produce the positive social effects related to automatic mimicry.

In this study, each participant entered a CVE and listened as an embodied agent read a persuasive message. The agent either mimicked the participant's head movements or played back head movements from a different participant. We predicted a chameleon effect, in that participants would be more persuaded by the mimicking agent than the nonmimicking agent.

METHOD

Design

The design included three between-subjects variables: *participant's gender* (male or female), *agent's gender* (male or female), and *agent's behavior* (mimic or recorded). The latter two variables were manipulated. In the *mimic* condition, three dimensions (pitch, yaw, and roll) of the agent's head movements exactly mimicked those of the participant at a 4-s delay. This delay was chosen because previous work in CVEs had demonstrated that a 4-s delay was optimal in minimizing detection of mimicry and maximizing responsiveness in terms of interactivity (Bailenson et al., 2004). In the recorded condition, the agent's head movements were an exact replay of the movements of a previous participant in the mimic condition; a different mimic recording was used for each participant in the recorded condition. In other words, the agent demonstrated the exact same movements in the two conditions. Figure 1 (bottom) shows the male and female three-dimensional models utilized as agents.

In both behavior conditions, the agent blinked (randomly, according to a computer algorithm based on human blinking behavior) and exhibited lip movements driven by the amplitude of the recording of the persuasive passage. The agent exhibited no behaviors other than lip movements, head movements, speech, and eye-blinks.

Materials

The CVE in which participants were immersed is depicted in Figure 1 (middle). In the virtual environment, participants were seated at a table, facing an embodied agent. They were able to see the head and shoulders of the agent. The same androgynous body was used for male and female agents.

Participants

Participants were recruited from an introductory communication class and received course credit. There were 47 females (24

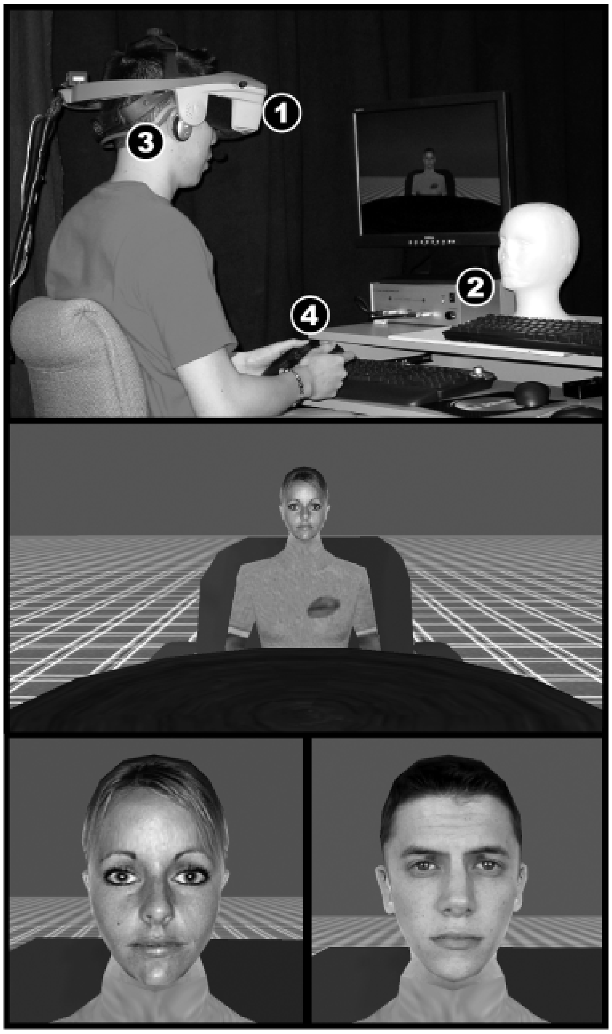

Fig. 1. The immersive virtual environment system used in this study (top), a participant's view of the virtual room (middle), and a close-up view of the three-dimensional models of female and male embodied agents (bottom). The numbered components of the system are the orientation-tracking sensor (1), image generator (2), head-mounted display (3), and game-pad input device (4).

in the mimic condition, 23 in the recorded condition) and 22 males (11 in the mimic condition, 11 in the recorded condition). Participants were randomly assigned to one of the four experimental conditions resulting from crossing the agent's gender and agent's behavior variables, with the constraint that the first 3 participants were placed in the mimic condition so we could obtain head recordings to use in later recorded conditions.

Procedure

When participants arrived at the laboratory, an experimenter instructed them on how to wear and adjust the virtual reality equipment (see Bailenson et al., 2002, for technical details) and how to use the game pad (see the top illustration in Fig. 1) to answer Likert-scale questions. Once immersed, participants found themselves seated at a table directly across from an embodied agent, whose gender and behavior depended on the assigned condition. Once participants were situated, the virtual agent delivered a persuasive message (based on work by Guadagno & Cialdini, 2002) advocating a campus security policy making it mandatory for students to always carry their identification. Female agents delivered the message in a recorded female voice, and male agents delivered the message in a recorded male voice. The length of each voice recording was 195 s.

The agent disappeared after delivering the recorded message, and a blank screen filled participants' view. Participants then indicated their agreement with four different statements discussing the plausibility and advantages of the campus security policy, one at a time, using a fully-labeled 7-point Likert scale, ranging from −3, *strongly disagree*, to +3, *strongly agree*. Responses were registered using the game pad. Next, participants removed the head-mounted display and used pen and paper to answer questions about their impression of the agent and the agent's social presence, again using scales from −3 to +3. Finally, participants wrote four separate open-ended paragraphs concerning their experience in virtual reality and the agent's head movements.

Measures

Effectiveness of the Agent

We created one composite measure of the agent's effectiveness by taking the mean response to the 4 agreement questions (how much the participant agreed with the agent's persuasive message), 13 questions on impression of the agent (how positively the participant evaluated the agent on a variety of trait measures; developed by Guadagno & Cialdini, 2002), and 8 questions on the agent's social presence (how realistic participants perceived the agent to be; based on Slater et al., 2002). Cronbach's alpha for this composite measure of these 25 items was .87. Our hypothesis was that mimicking agents would be more effective than nonmimickers.

Head Movements

We recorded participants' side-to side (i.e., yaw) head movements at approximately 12 Hz and determined the maximum value (in degrees) of deviation from the straight-ahead position (i.e., looking directly at the agent's eyes). Our hypothesis was that head movements would serve as an approximation of visual attention, and that participants would look farther away from the agent in the recorded condition than in the mimic condition because mimicking agents would be more effective at keeping participants' attention.

Mimicry Detection

Two independent raters, blind to experimental condition, read the four open-ended paragraphs from each participant, and each rater assigned a score of 1 to participants they believed detected the mimic algorithm and a score of 0 to participants they believed did not detect the mimic algorithm. If either rater gave a participant a 1, that participant was removed from the sample. In total, 8 participants (7 from the mimic condition, 1 from the recorded condition) were removed, so that the final number of participants was 61. The two raters disagreed for only 3 participants. We did not explicitly ask participants if they noticed the mimicry because, during pilot testing, even participants who clearly had no idea that the agent had mimicked them would claim to have noticed it when explicitly asked.

RESULTS

Effectiveness of the Agent

We ran an analysis of variance with three between-subjects independent variables (participant's gender, agent's gender, and agent's behavior) and agent's effectiveness as the dependent variable. There was a main effect of agent's behavior, with mimicking agents rated as more effective ($M = 0.58, SD = 0.59$) than recorded agents ($M = -0.07$, $SD = 0.62$), $F(1, 53) = 13.74, p < .001, \eta^2 = .21$. No other main effects or interactions were significant (all Fs were less than 1 and no η^2s were more than .01). This main effect did not change when covariate measures quantifying the head movements of either the participant or the agent were included. Table 1 shows results for the three underlying measures of the agent's effectiveness.

Head Movements

We examined the sample of yaw movements and removed a single outlier whose maximum side-to-side movement was more than 4 standard deviations above the population mean. We then ran an analysis of variance with three between-subjects independent variables (participant's gender, agent's gender, and agent's behavior) and maximum head movement as the dependent variable. There was a main effect of agent's behavior, with participants interacting with recorded agents straying farther away from center ($M = 38.46$, $SD = 36.35$) than those interacting with mimicking agents ($M = 24.21$, $SD = 25.87$), $F(1, 52) = 5.60, p < .02, \eta^2 = .10$. There was also a main effect of participant's gender, with male participants straying farther away from center ($M = 46.49$, $SD = 40.93$) than female participants ($M = 24.28, SD = 24.31$), $F(1, 52) = 7.90, p < .01, \eta^2 = .13$. There was no significant main effect of agent's gender, and no interactions were significant. Furthermore, there was no significant correlation between head movements and agent's effectiveness, $r(61) = -.08, p > .5$.

If participants moved their heads more than 28° in either direction, the agent was no longer in view. Consequently, on average, participants in the mimic condition and female participants did not turn their heads such that the agent was out of their field of view, whereas participants in the recorded condition and males did.

TABLE 1
Results for the Three Measures of the Agent's Effectiveness

Measure	Number of items	α	Mimic condition Mean	Mimic condition *SD*	Recorded condition Mean	Recorded condition *SD*	p[a]
Social presence	8	.81	0.07	1.15	−0.89	1.08	<.001
Agreement	4	.79	0.21	1.09	−0.32	1.16	.07
Agent impression	13	.89	1.06	0.76	0.39	0.77	<.001

[a]Results from independent-samples t tests of the difference between conditions.

DISCUSSION

In this experiment, an embodied agent that mimicked the head movements of participants was viewed as more persuasive and likable than an agent that utilized recorded head movements. In addition, participants interacting with mimicking agents on average did not turn their heads such that the agent was outside their field of view, whereas participants interacting with recorded agents did turn their heads away from the agent at times. Finally, very few participants explicitly noticed that the agent was in fact mimicking their movements.

This study raises questions concerning the distinction between contingent behaviors and mimicking behaviors. In addition to being a chameleon, the mimicking agent was responsively interacting with the participant and demonstrating superior eye gaze (Garau et al., 2003). Therefore, it is not clear whether the reason for the greater effectiveness of the mimicking agent in this study was that the agent was mimicking the participants' exact movements or merely that the agent was acting in a manner that was contingent on the participant's behavior.

When people engage in communication, one of the primary behaviors they utilize to demonstrate interactional synchrony is mimicry. In future work, we plan on teasing apart synchrony and mimicry by programming the agent to respond in a modality different from the one that it is reacting to (e.g., having the agent speak when the participant moves his or her head exactly 10°). Moreover, the agent could exhibit the exact same behavior as the participant, but much later on in the interaction, when the behavior is no longer responsive. In this sense, the behavior would be similar but not contingent.

It is important to note that in the current study, the interaction was limited in that there was no verbal turn taking between the participant and the agent. In future work, we plan on studying more involved interactions. Nonetheless, the implications of the current findings are potentially far-reaching. Prior research has demonstrated that mimicking humans are viewed more positively (Chartrand & Bargh, 1999; Suzuki, Takeuchi, Ishii, & Okada, 2003) and gain higher reward (van Baaren et al., 2003) than nonmimickers. The current study provides two notable advancements to this work.

First, the power of the chameleon effect persists even when the person being mimicked is fully aware that the mimicker is the embodiment of a nonhuman, artificial intelligence agent. This finding is quite in line with previous research indicating that the strength of the chameleon effect is independent of conscious awareness (Chartrand & Bargh, 1999), as well as with work indicating that people attribute personalities to computers and prefer computer personalities that are similar to themselves (Moon & Nass, 1996). Nonetheless, the probability that humans will interact with nonhuman mimickers is extremely high given the amount of time people spend on-line (Yee, in press). By demonstrating the benefits mimicry confers even to nonhuman agents, our findings also dovetail well with theories positing that mimicry is an adaptation that serves a social function (Chartrand, Maddux, & Lakin, 2004; Lakin et al., 2003). Future research should examine interaction between humans and virtual agents embodied as nonhumans—such as animals or very simple characters. On the basis of the work of Blascovich et al. (2002), we predict that the behavioral effects will persist regardless of the photographic form of the agent.

Second, now that mimicry has been used on a digital level, future work can examine more fine-grained mimics, such as probabilistic mimics and scaled mimics, which should be trivial to implement using simple existing algorithms. Mimicry filtered via a scale or probability factor should be even more difficult to detect than the delayed mirroring used in the current study. Whether in immersive virtual reality, on-line chat rooms, or video games, algorithmic mimics may become commonplace, with agents mimicking users as frequently as their designers want, as subtly or as obviously as they are programmed to do. Consequently, embodied agents should be uniquely versatile chameleons.

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