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# Virtual interpersonal touch: Haptic interaction and copresence in collaborative virtual environments

**Jeremy N. Bailenson · Nick Yee**

**Abstract** As digital communication becomes more commonplace and sensory rich, understanding the manner in which people interact with one another is crucial. In the current study, we examined the manners in which people touch digital representations of people, and compared those behaviors to the manner in which they touch digital representations of nonhuman objects. Results demonstrated that people used less force when touching people than other nonhuman objects, and that people touched the face with less force than the torso area. Finally, male digital representations were touched with more force than female representations by subjects of both genders. We discuss the implications of these data to the development of haptic communication systems as well as for a methodology of measuring the amount of copresence in virtual environments.

**Keywords** Presence · Social touch · Haptic interaction · Collaborative virtual environments

## 1 Introduction

While collaborating and communicating digitally will not replace face to face interaction anytime in the foreseeable future, there are advantages to digital interaction in terms of cost, safety, and efficiency [26]. One criticism of digital communication is that the interaction tends to be stark, largely due to either the lack of multiple communication channels (e.g., voice, touch, gestures) or the difficulty in coordinating those communication channels [40]. While it is certainly the case that digital communication functions quite well when interaction is limited to a single channel (cellular phone conversations are commonplace), as communication systems grow to allow more channels of information to integrate in psychologically meaningful ways, more and more people will come to rely on using multiple channels during remote communication.

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### 1.1 Related work

*Collaborative virtual environments and copresence* Researchers have been exploring the use of collaborative virtual environments (CVEs) for applications such as distance education [30], training simulations [31, 37], therapy treatments [23] and for social interaction venues [8]. While these applications are not yet commonplace, in certain areas of entertainment such as collaborative online video games, people are integrating multiple channels ranging from expressed nonverbal behaviors to voice and even to some touch via force feedback. These online games are becoming extremely popular with a substantial proportion of the population of many countries spending significant times playing and collaborating in these venues [44, 45].

While most research has proceeded historically on the technical development side of CVEs (see [16] for a review), there has been a large surge recently on understanding social interaction inside of CVEs. Much of this work has been geared towards understanding the nature of social interaction in digital space, and comparing the amount of *copresence* (also referred to as *social presence*), the degree to which people experience their digital counterparts as actual people.

One of the most difficult aspects of studying the concept of copresence lies in both defining it and measuring it. There is much debate concerning the theoretical parameters of presence with digital representations (see [27] for a recent review). One of the most widely used assessment tools for discussing and measuring presence is questionnaires—simply asking people inside CVEs about the quality of the interaction and the degree of connection with other people in the digital space. However, there is a growing body of researchers within the copresence research field that argue that the use of self-report measures such as questionnaires will never be sufficient as a measurement tool. Some arguments in support of this claim are: a) the extremely abstract nature of presence questionnaires (e.g., what exactly does it mean to say that another person feels ‘present’?), b) the pressure of largely obvious demand characteristics, the tendency of participants to fill out questionnaires in a certain way because they are attempting to fulfill or thwart the experimenter’s goals, and c) the fact that the underlying latent construct itself is so difficult to explicate. Indeed, in a clever attempt to get participants to quantify the ‘colorfulness’ of an experience, Slater [39] demonstrated that while it is possible to get a high reliability of questionnaires, that these measures actually can be the manifestation of the wrong latent construct. In other words, participants easily mapped the abstract questions about color on an underlying latent construct (e.g., pleasantness), the questionnaire in no way tapped into any idea subjects had concerning actual color. Similarly, when measuring presence via questionnaires, subjects, when faced with a quandary due to the abstractness of the questions and the novelty of the situations in which the questions are raised, simply map the questions onto some other underlying construct that is more reasonable to them.

Consequently, one argument is that the best way to achieve a measurement tool of copresence is not to listen to what people say in response to direct inquiries about presence, but instead to observe their behavior and see if their behavior coincides with what one would expect to be a high-presence behavior (see [29], for an early explication of this notion). Not surprisingly, there are many researchers exploring the use of observed behaviors as a proxy for copresence (e.g., [2, 3, 7, 8, 13, 19, 28, 32, 35, 36].

Recent empirical work has directly compared the use of self report questionnaires against other types of less direct but more objective measures such as nonverbal behavior, indirect verbal behavior, and task performance in immersive virtual environments [1, 4, 5]. Those studies have all demonstrated that the more indirect, objective behaviors consistently demonstrated statistically reliable differences in experimental manipulations (e.g., virtual human fidelity, difference between agents and avatars, anthropomorphism of virtual humans, situational contexts), while self report questionnaires did not. In other words, manipulations that theoretically should have made drastic changes in a subject's immersive experience did in fact change their behavior in the virtual environment but not their responses on self report presence questionnaires.

*Virtual Interpersonal Touch* In previous work, we have explored a concept called Virtual Interpersonal Touch (VIT), the phenomenon of people interacting via haptic devices in real-time in some virtual environment [6]. In those studies, we used relatively basic haptic devices to explore the expression of emotion through VIT. Subjects utilized a 2° of freedom force-feedback joystick to express seven emotions, and we examined various dimensions of the forces generated and subjective ratings of the difficulty of expressing those emotions. Furthermore, a separate group of subjects attempted to recognize the recordings of emotions generated by the first group of subjects. Results of this study indicated that humans were above chance when recognizing emotions via virtual touch, but not as accurate as people in a control condition who expressed emotions through non-mediated handshakes.

Studying touch in virtual environments is important for many reasons. First, we know that in physical space, touch tends to increase trust. For example, waiters who touch their customers when returning change receive bigger tips [17, 24, 41]. Touch is utilized to add sincerity and to establish trust [11], to augment the significance of a gesture via arousal, and to adhere to ritualized norms such as handshakes [14].

A number of researchers have designed systems that allow two users to interact via VIT. White and Back [43] provided a mechanism to simulate the feeling of arm wresting over a telephone line, and Fogg et al. [18] discussed networked haptic devices for game playing. Brave et al. [9] utilized force-feedback devices as a way to enable simultaneous physical manipulation and interaction by multiple parties. Furthermore, Kim and colleagues [25] have developed haptic interaction platforms that allow multiple users to experience virtual touch while solving numerous difficulties relating to network delay. There have been other notable examples of projects geared towards allowing virtual interpersonal touch [15, 20, 33, 34, 42].

While there has been work on the design side of VIT, very little is known about the psychological effects of haptic communication, though some research has begun to explore this issue. Ho et al. [22], ran experiments in which participants used collaborative haptic devices, and could feel the digital avatars of one another while performing tasks. Their results demonstrated that adding touch to a visual interaction improved performance on a spatial task and increased ratings of "togetherness" (see also [38]). Brave et al. [10] presented subjects with a screen based maze. Subjects were either trying to compete or cooperate with an alleged other player, and they either received haptic feedback or visual feedback from the other alleged player. Their results demonstrated that haptic feedback caused changes in trust among the players.

In sum, while there have been many efforts to develop VIT systems on the design side, only a few studies have systematically examined the use of VIT during social interaction. The current study is unique in that it uses VIT as a way to gauge how realistic a social interaction is in regards to copresence.

*Overview of experiment* The current study had two goals. The first was to examine how people virtually touch representations of other people inside of CVEs. In other words, while there has been much work dedicated to studying haptic devices that allow people to interact with inanimate objects, to our knowledge this is one of the first to objectively examine people touching other people within digital space. By exploring the patterns of haptic interaction, we can learn better way to design and study haptic devices, CVEs, as well as other forms of digital media. Consequently, the design of digital devices can improve as a consequence of this work. The second goal was to attempt to use haptic devices as a benchmark for copresence. If people experience high degrees of copresence from a digital representation, then they should touch that representation in a manner differently from inanimate, nonhuman representations which elicit low amounts of copresence. Only by creating a reliable measure of how real social interaction is in virtual environments can we proceed to design optimal collaborative, interactive systems.

## 2 Method

### 2.1 Design

In a within-subjects design, participants used a haptic device to “clean” dirt particles from a variety of objects in a desktop virtual environment. Participants were presented with a number of human models that varied by Gender (male or female) and were asked to clean dirt particles that were either on the face or torso of the model. Participants were also asked to clean dirt particles from the upper or lower part of a cylindrical object. Participants completed two trials for each combination, and these 20 trials were presented in random order on twenty unique faces (eight male faces and eight female faces) and cylindrical objects (four of different shapes).

### 2.2 Participants

Forty undergraduate students (23 female, 17 male) participated in the study for course credit.

### 2.3 Apparatus

*Haptic device* The haptic device used was a Sensable Phantom Omni with 6° of freedom of positional sensing (*x*, *y*, *z*, pitch, yaw, and roll). The device is able to provide force feedback on the *x*, *y*, and *z* planes with a maximum exertable force of 3.3 N. The force feedback workspace is approximately 16.3 cm (width)×12.2 (height)×7.1 (depth) in. The Phantom Omni has a physical footprint of approximately 18×20 cm, as shown in Fig. 1.

*Immersive tracking and display apparatus* The technology used to render the immersive environment is described in detail in Bailenson et al. [2] and depicted in Fig. 1. The head mounted display (HMD) contains a separate display monitor for each eye (50° horizontal by 38° vertical field-of-view with 100% binocular overlap) and the graphics system renders the virtual scene separately for each eye (in order to provide stereoscopic depth) at approximately 60 Hz. In other words, as a participant moved his or her head, the system redrew the scene 60 times a second in each eye in order to reflect the appropriate movements. Using an inertial tracking system for orientation with low latencies (i.e., the delay between a user’s movement and the system’s detection of that movement was less than 40 ms), it was possible for participants to experience realistically dynamic visual input.

*Virtual environment* We integrated the haptic device with the virtual reality platform Vizard 2.17. The haptic device allowed movement of a small sphere (depicted in Fig. 2) that

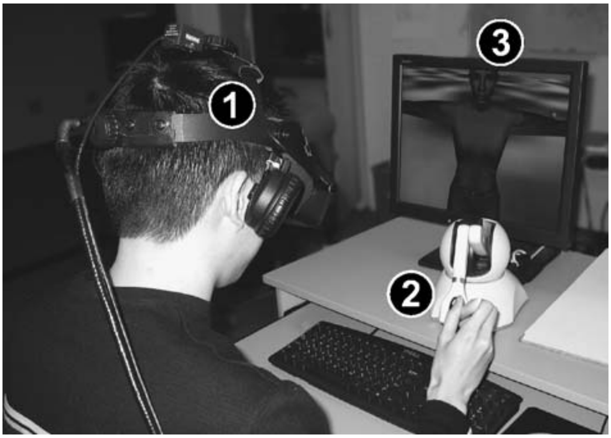

**Fig. 1** Participant wearing head-mounted display (*1*) while using the Phantom Omni (*2*). To help research assistants monitor participants, the computer screen (*3*) shows what the participant is seeing in the head-mounted display

represented the point of contact of the tip of the phantom device in the rendered virtual environment. The haptic device also provided force-feedback as the small sphere collided against other models in the virtual environment.

## 2.4 Materials

*Human and cylindrical models* Face models were generated using the software 3DMeNow. The software processes a front and profile photograph of an individual's head to construct a realistic 3D head bust. We used the front and profile photographs of an actual person to create the two models for that condition. These head busts were then imported and attached to existing body models within the Vizard platform. The cylindrical object was a roughly shaped oblong object created in a 3D modeling platform and then imported into Vizard.

*Dirt particles* The dirt particles were small, gray, pebble-sized objects modeled in a 3D modeling platform and imported into Vizard, as shown in Fig. 2.

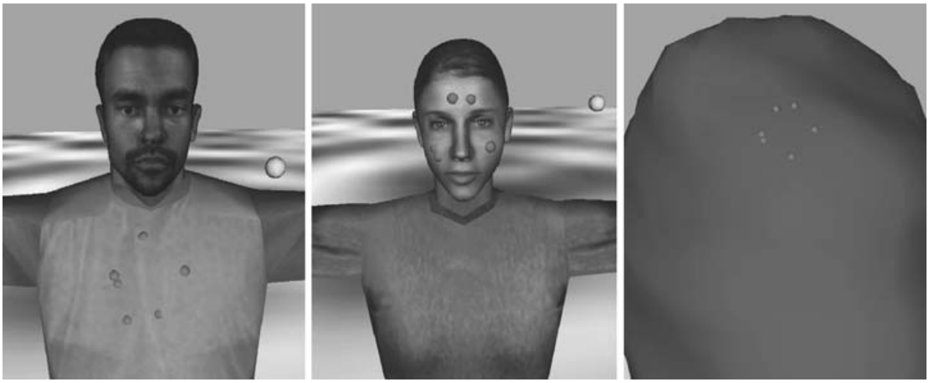

**Fig. 2** Examples of dirt spots on 2 of the 20 models of virtual people and one of the nonhuman objects. The larger sphere is the pointer controlled by the participant

### 2.5 Procedure

After informed consent, the research assistant explained to the participants that they would be presented with a series of people and objects in the desktop virtual reality environment. Participants were told that they could interact with this virtual environment via the haptic device. To get participants accustomed to movement and force-feedback of the haptic device, they practiced using a demonstration involving moving a cube around a small boxed area. Participants were told to move the cube first to the top left corner and then to the bottom right corner.

After this practice period, participants were told that the virtual people and objects they were about to see would have “dirt spots” on them. Their task was to use the haptic device to “clean” these spots off the object by moving their yellow spherical pointer into the dirt spot. There would be six dirt spots on each person or object, and participants had to remove all six dirt spots to proceed to the next virtual person or object. Participants were also told that the order in which they removed the dirt spots was not important.

The experimental script then presented the 20 virtual people and objects in a randomized order for each participant, with the one constraint that the order of face placement and torso placement of the spots alternated. This constraint was placed in order to prevent participants from getting into a set motor-movement routine without having to move the haptic device at all. For the face conditions, dirt spots were never placed on the eyes, nostrils, or mouth area of the model. By randomizing the order of experimental conditions, across experimental participants we prevent biases due to either training effects or fatigue effects.

## 3 Results

The haptic device allowed us to track the precise force participants used throughout the study in Newtons. For each participant, we measured the amount of force exerted every second in each of the conditions. Because force is only exerted when the participant touches the person or the object, if we took the average of force applied, we would inadvertently be including the times when the subject was not touching the object (i.e., 0 force). Thus, for this measure of force, we took the average of the nonzero force applied in each condition. Table 1 shows the estimated marginal means and standard error of the mean force by experimental condition.

We conducted an Analysis of Variance, a standard statistical procedure for determining whether or not differences between experimental conditions are greater than one would expect by chance. This analysis computes an $F$ statistic which can be roughly described as a ratio of differences due to experimental manipulations to the error one finds in the sample, a $p$ value which is the probability that the difference observed between experimental conditions occurred due to chance, and partial $\eta^2$ which is an approximation of how much variance in the overall dataset the experimental manipulation accounts for.

**Table 1** Estimated marginal means and standard errors by subject gender, target gender, and target area

| | Female target | | Male target | | Object target | |
|---|---|---|---|---|---|---|
| | Face | Body | Face | Body | Face | Body |
| Male subject | .44 (.03) | .52 (.05) | .51 (.04) | .56 (.50) | .69 (.07) | .72 (.08) |
| Female subject | .40 (.02) | .45 (.04) | .42 (.03) | .50 (.04) | .56 (.06) | .59 (.07) |

The independent variables in the analysis were *Subject Gender* as the between-subjects factor, *Target Gender* and *Area* (face vs. torso) as the within-subjects factors, and average nonzero force as the dependent variable. The effect of Target Gender was significant ($F[1, 38]=12.71$, $p=.001$, partial $\eta^2=.25$). Male targets were touched harder ($M=.50$, SE=.04) than female targets ($M=.45$, SE=.03). There was also a significant effect of Area ($F[1, 38]=6.60$, $p=.01$, partial $\eta^2=.15$). Torso areas were touched harder ($M=.51$, SE=.04) than face areas ($M=.45$, SE=.03). As Table 1 demonstrates, there were no significant differences between male and female participants in how hard they touched ($F[1, 38]=2.26$, $p=.14$, partial $\eta^2=.06$). None of the interactions were significant ($F\text{s}<1.60$, $p\text{s}>22$, partial $\eta^2<.04$).

To test whether participants touched objects harder than people, we conducted another repeated measures ANOVA with Subject Gender as the between-subjects factor, Target State (object vs. human) as the within-subjects factor, and average nonzero force as the dependent variable. The effect of Target State was significant ($F[1, 38]=38.29$, $p<.001$, partial $\eta^2=.50$). Participants touched the object harder ($M=.64$, SE=.04) than they touched another person ($M=.48$, SE=.02). None of the other factors or interactions was significant ($F\text{s}<1.50$, $p\text{s}>.23$, partial $\eta^2<.04$).

## 4 Discussion

In the current paper, participants interacted with digital models of people via a haptic device. Specifically, they attempted to remove dirt spots from male and female faces and torsos as well as dirt spots from similar locations on nonhuman objects. Results indicated that people were touched with less force than nonhuman objects, the face was touched with less force than the torso, and that female digital human representations were touched with less force than male representations.

These findings all converge towards an implicit, behavioral measure of copresence. People interact haptically with virtual people in a measurably different manner from other nonhuman objects. And when people interact haptically with virtual people, they differentiate between different areas of the body. Indeed, haptic differentiation should only occur when there is a high amount of copresence. In a virtual environment where copresence is low, agents would not be treated as social actors and we might expect lower haptic differentiation between the agent and the nonhuman object. Finally, people touched male and female representations with different amounts of force, which is consistent with previous work demonstrating gender differences in touch behavior (Chaplin et al. [14]).

With the same logic of the Implicit Association Task [21], a measure commonly used by social scientists which relies on differential reaction times to measure latent race or gender biases, one could imagine a haptics task that used differential levels of force to measure copresence. Moreover, such an implicit measure would avoid the problems of questionnaire-based measures of copresence (i.e., phrasing, validity, etc.). And indeed, if copresence is important because it influences how people behave in virtual environments, then behavioral measures are a direct and meaningful way to measure the degree of copresence within a virtual environment.

One limitation of our study was that the task revolved around cleaning rather than a form of social touch (i.e., reassuring pat, tapping someone on the shoulder to get their attention, etc.). Future studies might employ instead a paradigm where the touch itself is social. For example, participants might be asked to tap the shoulders of avatars facing away from them.

Our findings suggest several avenues of research. In the same vein of using haptic devices to measure implicit attitudes, one might imagine an implicit racism task based on haptic interaction. Just as participants apply different amounts of force on different parts of the body without conscious awareness or deliberation, a similar "cleaning" task using avatars of different skin tones or ethnicities might reveal a user's attitudes towards different racial groups. Another line of research might explore the opposite of the question we addressed. Namely, if the use of a haptic device in a social interaction encourages a user to think about touching the other person, then this might increase the social status of the other avatar. Forcing an interactant to explicitly consider the behavior of touch in a CVE may trigger thoughts in the user as to where and how to touch the other avatar and forces the user to consider it as a social actor. In other words, the addition of a haptic tool in a virtual environment where users can touch each other may in and of itself increase copresence. Finally, it would also be interesting to study the effects of being touched in a virtual environment. While previous studies have explored mutual force-feedback, it would be interesting to study whether an agent that touched you would be perceived as more likeable in the same way that waiters get tipped more when they touch their customers.

Touch is a powerful nonverbal cue in face-to-face interaction. As research on CVEs proceeds, the use of haptic devices will allow for naturalistic use of virtual interpersonal touch. It may be the case that the power of touch in CVEs is actually more salient than in physical space, given that the forces can be selectively scaled up or down by interactants, applied in parallel from one interactant to multiple other interactants at the same time, and can be tailored specifically to specific users based on algorithmic profiles recorded by CVE systems.

In conclusion, in the current work, we have demonstrated that people touch digital representations of others in a manner consistent with experiencing high degrees of copresence and in a similar manner to what occurs in a face-to-face venue. Experimental participants touched human objects with less force than nonhuman objects, touched human objects with less force in the face than in the torso, and male avatars were touched with more force than female avatars. Future work should further explore the possibilities of virtual interpersonal touch in CVEs.

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## References

1. Bailenson JN, Aharoni E, Beall A, Guadagno R, Dimov A, Blascovich J (2004) Comparing behavioral and self-report measures of embodied agents social presence in immersive virtual environments. Paper presented at the 7th Annual International Workshop on Presence, Valencia, Spain
2. Bailenson JN, Beall A, Blascovich J (2002) Mutual gaze and task performance in shared virtual environments. J Vis Comput Animat 13:1–8
3. Bailenson JN, Blascovich J, Beall A, Loomis J (2003) Interpersonal distance in immersive virtual environments. Pers Soc Psychol Bull 29:1–15
4. Bailenson JN, Swinth K, Hoyt C, Persky S, Dimov A, Blascovich J (2005) The independent and interactive effects of embodied agent appearance and behavior on self-report, cognitive, and behavioral markers of copresence in Immersive Virtual Environments. Presence: Teleoperators and Virtual Environments 14:379–393
5. Bailenson JN, Yee N (2005) Digital chameleons: automatic assimilation of nonverbal gestures in immersive virtual environments. Psychol Sci 16:814–819
6. Bailenson JN, Yee N, Brave S, Merget D, Koslow D (2007) Virtual interpersonal touch: expressing and recognizing emotions through haptic devices. Hum Comput Interact 22(3):(in press)
7. Bente G, Rüggenberg S, Tietz B, Wortberg S (2004) Measuring behavioral correlates of social presence in virtual encounters. Paper presented at the International Communication Association Conference, May 27–31

8. Blascovich J, Loomis J, Beall A, Swinth K, Hoyt C, Bailenson J (2002) Immersive virtual environment technology as a methodological tool for social psychology. Psychol Inq 13(2):103–124
9. Brave S, Ishii H, Dahley A (1998) Tangible interfaces for remote collaboration and communication. Proceedings of CSCW '98: Conference on Computer Supported Cooperative Work, pp 169–178
10. Brave S, Nass C, Sirinian E (2001) Force-feedback in computer-mediated communication. In: Stephanidis C (ed) Universal access in HCI: Toward an information society for all, Lawrence Erlbaum Associates, Mahwah, NJ, pp 145–150
11. Burgoon J (1991) Relational message interpretations of touch, conversational distance, and posture. J Nonverbal Behav 15:233–259
12. Burgoon J, Walther J (1990) Nonverbal expectancies and the evaluative consequences of violations. Human Commun Res 17:232–265
13. Burgoon J, Bonito J, Bengtsson B, Ramirez A, Dunbar N, Miczo N (2000) Testing the interactivity model: communication processes, partner assessments, and the quality of collaborative work. J Manage Inf Syst 16:33–56
14. Chaplin WF, Phillips JB, Brown JD, Clanton NR, Stein JL (2000) Handshaking, gender, personality, and first impressions. J Pers Soc Psychol 79:110–117
15. Chang A, O'Modhrain S, Jacob R, Gunther E, Ishii H (2002) ComTouch: Design of a Vibrotactile Communication Device Proc. Paper presented at the ACM DIS 2002 Designing Interactive Systems Conference
16. Churchill EF, Snowdon D, Munro A (eds) (2001) Collaborative Virtual Environments. Digital Places and Spaces for Interaction. Springer Verlag: London, UK
17. Crusco AH, Wetzel CG (1984) The Midas touch: the effects of interpersonal touch on restaurant tipping. Pers Soc Psychol Bull 10:512–517
18. Fogg B, Cutler L, Arnold P, Eisback C (1998) HandJive: a device for interpersonal haptic entertainment. Paper presented at the CHI '98: Conference on Human Factors in Computing Systems
19. Garau M, Slater M, Pertaub D, Razzaque S (2005) The responses of people to virtual humans in an immersive virtual environment. Presence: Teleoperators and Virtual Environments 14:104–116
20. Goldberg K, Wallace R (1993) Denta-Dentata. Paper presented at the SIGGRAPH '93: International Conference on Computer Graphics and Interactive Techniques
21. Greenwald AG, McGhee DE, Schwartz JKL (1998) Measuring individual differences in implicit cognition: the implicit association test. J Pers Soc Psychol 74:1464–1480
22. Ho C, Basdogan C, Slater M, Durlach N, Shrinivasan M (1998) An experiment on the influence of haptic communication on the sense of being together. Paper presented at the BT Presence Workshop
23. Hoffman HG (2004) Virtual Reality Therapy. Scientific American Magazine, August 2004
24. Hubbard A, Tsuji A, Williams C, Seatriz V (2003) Effects of touch on gratuities received in same-gender and cross-gender dyads. J Appl Soc Psychol 33:2427–2438
25. Kim J, Kim H, Tay B, Manivannan M, Srinivasan M, Jordan J, Mortensen J, Oliviera M, Slater M (2004) Transatlantic touch: a study of haptic collaboration over long distance. Presence: Teleoperators and Virtual Environments 13:328–337
26. Lanier J (2001) Virtually there. April, 66–75. Scientific American, April, pp 66–75
27. Lee KM (2004) Presence, explicated. Commun Theory 14:27–50
28. Lee K, Nass C (2004) The multiple source effect and synthesized speech: doubly disembodied language as a conceptual framework. Human Commun Res 30:182–207
29. Loomis JM (1992) Distal attribution and presence. Presence: Teleoperators and Virtual Environments 1:113–119
30. Mantovani F (2001) Virtual reality learning: potential and challenges for the use of 3d environments in education and training. Towards cyber-psychology: mind, cognitions and society in the internet age. IOS Press, Amsterdam, ch. 12
31. Marsella S, Gratch J, Rickel J (2003) Expressive behaviors for virtual worlds, in life-like characters tools, affective functions and applications. In: Prendinger H, Ishizuka M (eds) Springer Cognitive Technologies Series
32. Meehan M, Insko B, Whitton M, Brooks F (2002) Physiological measures of presence in stressful virtual environments. ACM Trans Graph 21:645–653
33. Noma S, Miyasato M (1997) Embodying concept with haptic interface for thinking. Proceedings of 13th Human Interface Symposium pp 11–16
34. Oakley I, Brewster S, Gray P (2001) Solving multi target haptic problems in menu interaction. Extended Abstracts of ACM CHI 2001, pp 357–358
35. Parise S, Kiesler SB, Sproull S, Waters K (1996) My partner is a real dog: cooperation with social agents. Proceedings of Computer Supported Cooperative Work, pp 399–408
36. Reeves B, Nass C (1996) The media equation: how people treat computers, televisions, and new media like real people and places (reprint edition): Center for the Study of Language and Information

37. Rizzo A, Morie JF, Williams J, Pair J, Buckwalter JG (2004) Human emotional state and its relevance to military VR training. Paper presented at the International Conference on Human Computer Interaction
38. Sallnas E, Rassmus-Grohn K, Sjostrom C (2001) Supporting presence in collaborative environments by haptic force feedback. ACM TOCHI 7:461–476
39. Slater M (2004) How colorful was your day? Why questionnaires cannot assess presence in virtual environments. Presence: Teleoperators and Virtual Environments 13:484–493
40. Sproull L, Kiesler S (1986) Reducing social context cues: electronic mail in organizational communication. Manage Sci 32:1492–1512
41. Stephen R, Zweigenhaft R (1985) The effect on tipping of a waitress touching male and female customers. J Soc Psychol 126:141–142
42. Strong R, Gaver W (1996) Feather, scent and shaker: supporting simple intimacy. CHI'96 Extended Abstracts, p 444
43. White N, Back D (1986) Telephonic Arm Wrestling, from http://www.bmts.com/normill/artpage.html
44. Woodcock B (2005) MMOG Chart, from http://www.mmogchart.com/
45. Yee N (2006) The demographics, motivations, and derived experiences of users of massively multi-user online graphical Environments. Presence: Teleoperators and Virtual Environments 15:309–329

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Bailenson's main area of interest is the phenomenon of digital human representation, especially in the context of immersive virtual reality. He explores the manner in which people are able to represent themselves when the physical constraints of body and veridically rendered behaviors are removed. Furthermore, he designs and studies collaborative virtual reality systems that allow physically remote individuals to meet in virtual space, and explores the manner in which these systems change the nature of verbal and nonverbal interaction.

**Nick Yee** is currently a PhD student in the Department of Communication at Stanford University doing research in immersive virtual reality and online games. Over the past 5 years, he has surveyed over 35,000 MMORPG players on a wide variety of issues, such as age and gender differences, motivations of play, relationship formation, and problematic usage. At Stanford's Virtual Human Interaction Lab, he works with Jeremy Bailenson in designing and analyzing experimental studies exploring social interaction in virtual environments.