Force-Feedback in Computer-Mediated Communication

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ABSTRACT

This study investigates the effect of force-feedback in computer-mediated communication. Participants completed a screen-based maze task with an alleged remote participant in a 2 (task characteristics: cooperative vs. competitive) by 2 (modality: haptic/force-feedback vs. visual) balanced, between-participants experiment. There were a number of cross-over interactions. In the competitive task, participants felt more powerful and more positively overall when interacting through force-feedback than when interacting visually. They also liked the other participant more and trusted them more. The opposite results were obtained for the cooperating participants. Implications for including force-feedback in computer-mediated communication are outlined.

Keywords

Force-feedback, haptic, touch, tangible interfaces.

INTRODUCTION

Human-computer interaction has traditionally focused on audio-visual interfaces. Over the past several years, however, the research community has given new consideration to the tactile dimension of mediated interaction [5]. Recent work by Ishii's Tangible Media Group, for example, has explored the use of real-world physical objects as interface elements in what they term Tangible User Interfaces (TUIs) [10]. An alternate approach has been the enhancement of traditional graphics-based interfaces through the use of force-feedback pointing devices. Commercially-available force-feedback devices, such as Immersion's FEELit mouse and Sensible's PHANToM, can serve a dual role as both input device and force display, enabling users to physically interact with onscreen objects and worlds.

Current research into force-feedback (haptic) interfaces falls into three main categories. The first is simulation, where the goal is to enhance the sense of realism in virtual worlds (included in this category are VR applications such as surgery training and gaming) [18]. The second is scientific visualization, where force output serves as an additional channel for exploring complex data sets. Finally, a growing body of literature has begun to investigate the potential for force-feedback to improve the efficiency of conventional GUI interactions [17][15][13].

All of the above research focuses exclusively on single-user interactions. However, the tactile dimension is potentially of great value not only in our interactions with the inanimate virtual world, but also in mediated interpersonal interactions. A few projects have begun to create such interactive systems. One of the first attempts at multi-user force-feedback interaction, *Telephonic Arm Wrestling* [23], provided a basic mechanism to simulate the feeling of arm wresting over a telephone line. *Denta-Dentata* [8] is an elementary "hand holding" device that communicates one bit of information over the phone line to activate a mechanism that can squeeze a user's hand. *Feather, Scent, and Shaker* [20] consists of a pair of linked "shaker" objects. Shaking one object causes the other to vibrate, and vice-versa. Fogg *et al*. [7] describe *HandJive,* a pair of linked hand-held objects for playing haptic games. Each object has a joystick-like controller that can be moved vertically or horizontally. A horizontal displacement of the local object causes a vertical displacement in the remote object, and vice-versa. *Kinesthetic Constructions* by Schena [19] explores the application of bilateral force-feedback to interpersonal communication. This is a network of large modern sculptures distributed around the world, where parts of each sculpture are hapticly connected to sculptures at other locations. *InTouch* [2] is a desktop device that employs force-feedback to create the illusion of a shared physical object over distance, enabling simultaneous physical manipulation and interaction.

Many of these projects report positive reactions from users based on informal user testing. However, a formal study has not been conducted to evaluate the effects of computer-mediated haptic communication. This paper presents an initial experimental study intended to fill this gap.

Although interaction through today's force-feedback devices is a far cry from real physical contact, one conceptual framework to begin thinking about multi-user force-feedback interactions is remote *touch*. Touch is a powerful means of communication—one that offers an immediacy and intimacy unparalleled by words or images. The firm handshake, an encouraging pat on the back, a comforting hug, all speaks to the profound expressiveness of physical contact. In the real world, touch can further serve as a powerful mechanism for reinforcing trust and establishing group-bonding [3][4]. Depending on context however, touch can also be utilized to assert dominance, display power, and even cause harm. For this reason, we use both a cooperative and a competitive task in our experiment.

Because real-world touch has been shown to have effects on affective state [1][6][16], interpersonal evaluation [6][9][22], and cooperative behavior [16][12], we measure each of these dependent variables.

METHOD

Participants

Participants were 48 university undergraduates enrolled in communication classes. Participants were randomly assigned to condition, with gender approximately balanced across conditions. All participants signed informed consent forms, were debriefed at the end of the experiment session, and received class credit for their participation.

Procedure

The experiment was a 2 (modality: haptic vs. visual) by 2 (valence of intent: benevolent vs. hostile, i.e. cooperative vs. competitive) balanced, between-participants design. Upon arrival to the lab, the participant was told that he or she would be working on some computer-based tasks with a participant in another room. The participant was then left with a consent form while the experimenter supposedly went to check if the participant and experimenter in the other room were ready to begin. In actuality, there was only one participant and all interaction with the supposed other participant was simulated by the computer (a reverse "Wizard of Oz" experiment).

After returning, the experimenter explained the first task, a maze, to the participant. This task was similar to a paper-and-pencil maze, except that it was done on the computer screen (see Figure 1). The keyboard's arrow keys controlled the movement of a cursor within the maze; the goal was to exit the maze as quickly as possible.

Maze Task

The maze task was described to the participant using a simplified version of the maze. The experimenter then explained that the other participant had already been through the maze several times and would now be observing the actual participants' performance. Depending on the condition, the participant was also told that the other participant would be trying either to help them through their maze (cooperative) or make it more difficult for them to complete the maze (competitive). The assistance or hindrance would come in the form of directional suggestions made either visually or hapticly, depending on condition. The experimenter then left the room and the participant began the maze task.

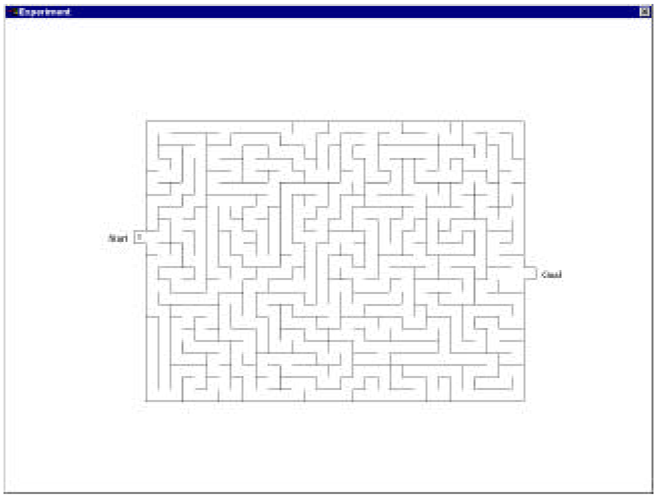

Figure 1. Maze used in maze task.

The maze task was chosen for two reasons. First, communication through touch seemed reasonable in the context of finding your way through a maze. Second, the maze task constrains the interaction in such a way that simulating interaction with another person is feasible (all suggestions were in one of four directions and occurred at key points within the maze).

After completing the maze task, the participant was instructed to fill out a paper-and-pencil questionnaire asking for his or her assessment of the interaction and the other participant.

Prisoner's Dilemma

The participant then returned to the computer for instructions on the second task, a variant of the two-player strategy game, the Prisoner's Dilemma. The Prisoner's Dilemma is often used in research as a measure of cooperative behavior [11][14]; we used a multi-round, but non-iterated version of the Prisoner's Dilemma derived from Terhune [21].

On each of 12 rounds, players must choose one of two moves (traditionally called Cooperate and Defect). On a given round, if both players Cooperate, both get a moderate point reward (e.g., 5 points). If one player Defects and the other Cooperates, the Defecting player "steals" points from the Cooperating player (e.g., the Defector gets 8 points, and the Cooperator loses 8 points). If both players Defect, both are penalized (e.g.. both lose 3 points).

The point rewards/penalties were different for each round and were displayed onscreen in two formats: a standard

Prisoner's Dilemma matrix (Figure 2) and a verbal description. The moves were labeled 'A' and 'B', but in the verbal description, 'A' was explained to be the cooperative move. Participants were asked to give their move as well as predict the other participant's move. Participants did *not* see any of the other participant's moves.

		Other	
		A	**B**
You	**A**	You: 5 Other: 5	You: -8 Other: 8
	B	You: 8 Other: -8	You: -3 Other: -3

Figure 2. Prisoner's Dilemma Matrix

This non-iterated format (i.e., computers' responses are *not* contingent on the participant) for the Prisoner's Dilemma was chosen so that every participant would receive the same responses, important so that the computer did not get into different feedback loops with different participants.

Manipulation

All manipulation took place in the maze task. Both valence of intent and the use of touch were manipulated.

Valence of Intent

To instantiate benevolent intent (cooperation), the participant was told that the other participant's score on the maze task would be a combination of both of their times through the maze. In other words, the other participant wanted the participant to do *well* and would therefore try to help as much as possible. All suggestions in this condition were in the correct direction to reach the exit.

Hostile intent (competition) was instantiated by telling the participant that the other participant would receive a score based on how much better or worse their time was than the participant's. In other words, the other participant wanted the participant to do *poorly* and would therefore try to "mess them up" while working on the maze. To be maximally confusing, half of the suggestions were correct and half were incorrect in this condition.

Modality

In the visual condition, suggestions came in the form of arrows appearing on the screen next to the maze. During a suggestion, the appropriate directional arrow was shown above, below, and to each side of the maze to ensure visibility (Figure 3). The arrows remained onscreen for 300mS.

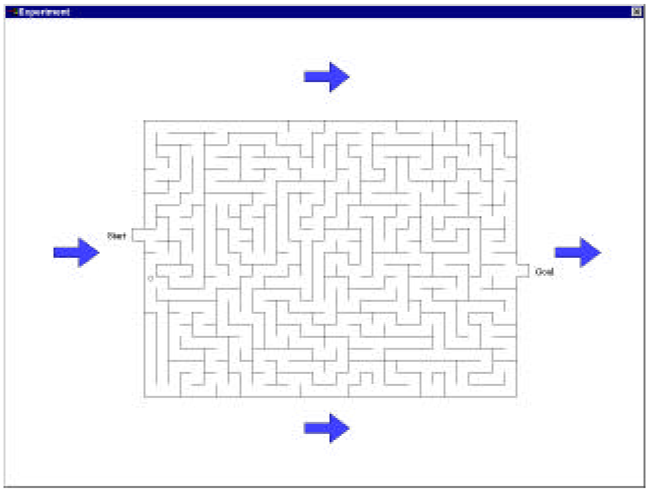

Figure 3. Maze with onscreen arrows suggesting a move to the right.

In the haptic condition, suggestions were made through "pushes" (directional forces) on a force-feedback joystick (Immersion Corporation's Impulse Engine 2000; see Figure 4). Participants in this condition controlled cursor movement in the maze with their dominant hand and held the force-feedback joystick with their other hand to receive the suggestions. The duration of the push was also 300mS, increasing in intensity from zero to maximum intensity over the first 150mS and then decreasing back to zero in the next 150mS.

Figure 4. Immersion's Impulse Engine 2000.

Measures

The behavioral measure in this study, *participant cooperation*, was measured behaviorally as the number of cooperative selections in the Prisoner's Dilemma.

Attitudinal measures were based on responses to a paper-and-pencil questionnaire. The questionnaire included two kinds of adjectives.

The first set of questions asked, “How well do each of the following adjectives describe how you feel,” followed by a series of adjectives. Each adjective was associated with a ten-point Likert scale anchored by “Describes Very Poorly” and “Describes Very Well.”

The second set of questions asked: “How well do each of the following adjectives describe the person you worked with,” followed by a series of adjectives. Each adjective was associated with a ten-point Likert scale anchored by “Describes Very Poorly” and “Describes Very Well.”

Based on theory and confirmed by factor analysis, we developed four attitudinal measures. All indices were highly reliable.

Feeling of power of the participant was comprised of three items: powerful, dominant, and in control (Cronbach’s alpha = .81)

Positive affect of the participant was comprised of seven items: comfortable, good, pleasant, happy, positive, successful, and capable (alpha=.88).

Liking of partner was comprised of five items: friendly, warm, likable, pleasant, compassionate, and attractive (alpha=.87)

Trust of partner was comprised of eight items: honest, not tricky, trustworthy, reliable, sincere, cooperative, helpful, and compassionate (alpha=.95)

RESULTS

Time on Maze

Time to solve the maze served as a manipulation check of valence of intent. As expected, cooperative participants solved the maze more quickly than did competitive participants, F(1,44)=7.58, p<.01 (see Figure 5). There was no effect for modality, and there was not a significant interaction.

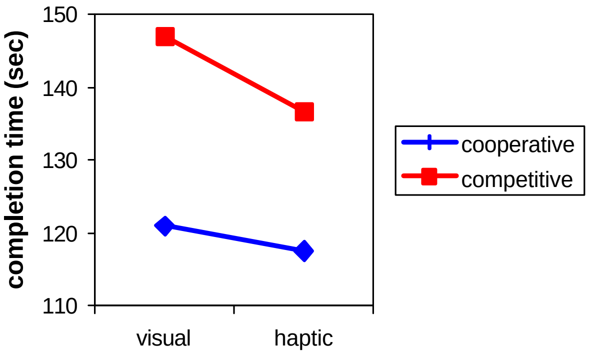

Figure 5. Time to complete the maze

Power Feeling

There was a significant cross-over interaction with respect to feeling powerful, F(1, 44)=10.89, p<.002 (see Figure 6). Touch participants felt more powerful in the competitive condition, but less powerful in the cooperative condition. As an artifact of the extreme value in the haptic-competitive condition, there was a main effect for intent, F(1,44)=6.44, p<.02.

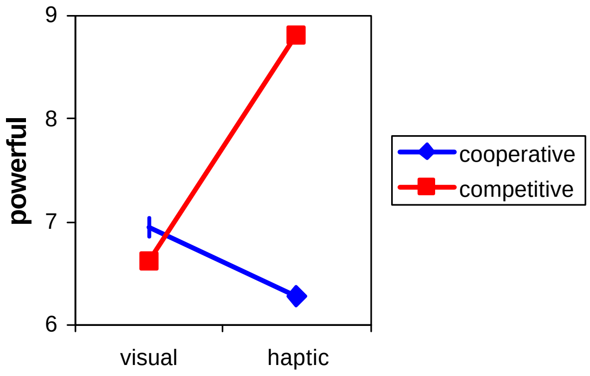

Figure 6. Feeling of Power

Participant Affect

There was a significant cross-over interaction with respect to affective state, F(1,44)=10.85, p<.002 (see Figure 7). Touch led to much more positive feelings in the competitive than in the cooperative conditions, while leading to slightly more negative affect in the cooperative condition. There was a main effect for modality F(1, 44)= 5.54, p<.02, which was an artifact of the extremely low liking for the competitive visual case.

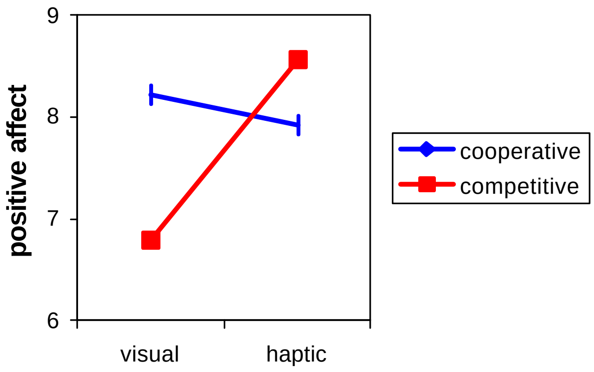

Figure 7. Positive Affect

Liking

There was a significant interaction between valence of intent and modality with respect to liking, F(1,44)=4.81, p<.03 (see Figure 8). Consistent with the previous results, cooperative participants liked the interaction partner when viewing onscreen arrows as compared to touch, while competitive participants liked their ostensible partner better in the haptic case. Not surprisingly, cooperative participants liked the interaction better than competitive participants, F(1,44)=26.86, p<.001. There was no main effect for modality.

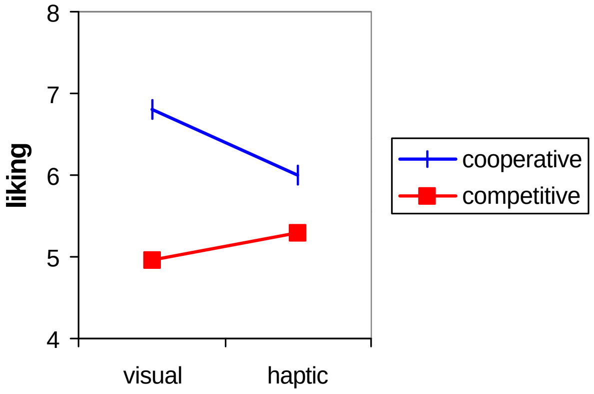

Figure 8. Liking of Ostensible Partner

Trust

There was a significant interaction between valence of intent and modality with respect to trust, F(1,44)=5.68, p<.02 (see Figure 9). Contrary to expectations, cooperative participants trusted their ostensible partner less when interacting via haptics as compared to visuals, while there was no difference in the competitive conditions. Not surprisingly, cooperative participants trusted their partners more than did competitive participants, F(1,44)=106.36, p<.001. There was no main effect for modality.

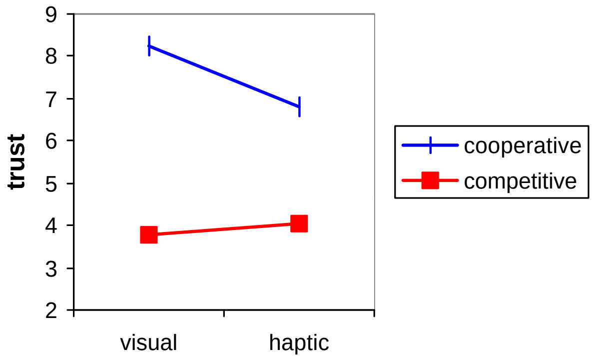

Figure 9. Trust of Ostensible Partner

Behavioral Cooperation

There was not a significant interaction with respect to the number of cooperative moves in the Prisoner's Dilemma, F(1,44)=.07, p>.79 (see Figure 10). There were no significant main effects for modality or valence of intent.

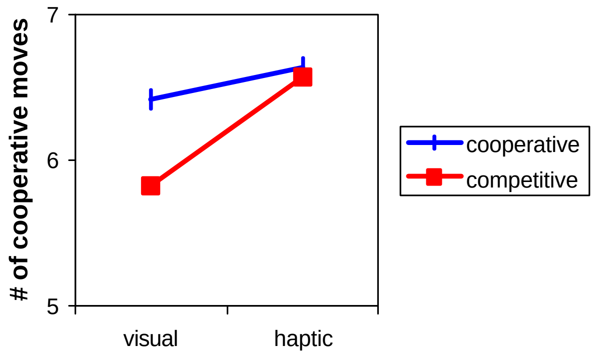

Figure 10. Number of Cooperative Moves

DISCUSSION

Communication via force-feedback had a dramatic effect on users' feelings about the interaction and user's perceptions of their interaction partners. Interestingly, touch did not have a *direct* effect on users' attitudes; instead, modality interacted with the perceived intent of the (ostensible) interaction partner.

The largest effects were in users' feelings of power and their affective state. Namely, in the competitive condition, interaction through touch made users feel more powerful and more positively overall. However, in the cooperative condition, the effect of touch was the opposite: Interaction through touch made users feel less powerful and less positively overall. This effect can be explained by considering the psychology of holding. Holding the joystick gives the participant a feeling of being in command of their partner. This is true because the forces on the joystick—though always felt—were not strong enough to overcome the participant's actions. In other words, the distant partner could influence the joystick, but the participant had final say over the joystick's position and movement. In the competitive condition, this gave the participant a clear sense of power. The participant's goal as to overcome their partner and the joystick served as a medium for establishing and reinforcing their dominance. Such dominance was not possible in the visual modality, since the arrows can only be ignored, not commanded.

In the cooperative condition, on the other hand, being in command of the other participant was useless. The participant was in a position of ineffectual authority, because command over the joystick didn't serve any practical or psychological end. The result as now the opposite: The participant felt powerless.

The results seen for affective state now have an obvious explanation. A participant who feels powerful would almost surely feel more positively overall; the opposite would be true for a participant who felt less powerful. It is also reasonable to expect that a participant who felt more powerful and positive would give more positive evaluations of the partner than a participant who feels more powerless and negative.

The lack of significant results in the Prisoner's Dilemma deserves discussion. First of all, judging from post-experiment interviews, it seems that many participants did not understand the task. Supporting this, participants often made moves that were completely illogical (Cooperating when they predicted the other person would Defect). Another part of the problem was that many of the students were familiar with the traditional iterated Prisoner's Dilemma and expected to see the other participant's moves. Yet another problem with those who knew of the game was that they "knew what to do" ahead of time and always chose Cooperate or Defect depending on what they remembered. So, although our variant of the Prisoner's Dilemma seemed the best choice, it may have been better to stick with the iterated Prisoner's Dilemma. This might have been more familiar and possibly more understandable, given that the effects of one's moves can be seen.

Conclusion

With the advent of commercial force-feedback devices, researchers are giving serious consideration to the incorporation of haptics into both HCI and CMC applications. The underlying sentiment is often that the added dimension of touch will inherently lead to more efficient and satisfying interfaces. The results of the present study, however, indicate that the effect of mediated touch can be positive *or* negative, depending on context. Much as touch in the real world, mediated touch is a psychologically complex phenomenon, requiring careful consideration before use. More work is clearly necessary before a set of guidelines for applying mediated touch can be developed, but this study will serve as a starting point for future investigation.

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