The Wobbly Table: Increased Social Presence via Subtle Incidental Movement of a Real-Virtual Table

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Abstract

While performing everyday interactions, we often incidentally touch and move objects in subtle ways. These objects are not necessarily directly related to the task at hand, and the movement of an object might even be entirely unintentional. If another person is touching the object at the same time, the movement can *transfer* through the object and be experienced—however subtly—by the other person. For example, when one person hands a drink to another, at some point both individuals will be touching the glass, and consequently exerting small (often unnoticed) forces on the other person. Despite the frequency of such subtle incidental movements of shared objects in everyday interactions, few have examined how these movements affect human-virtual human (VH) interaction. We ran an experiment to assess how presence and social presence are affected when a person experiences subtle, incidental movement through a shared real-virtual object. We constructed a real-virtual room with a table that spanned the boundary between the real and virtual environments. The participant was seated on the real side of the table, which visually extended into the virtual world via a projection screen, and the VH was seated on the virtual side of the table. The two interacted by playing a game of "Twenty Questions," where one player asked the other a series of 20 yes/no questions to deduce what object the other player was thinking about. During the game, the "wobbly" group of subjects experienced subtle incidental movements of the real-virtual table: the entire real-virtual table tilted slightly away/toward the subject when the virtual/real human leaned on it. The control group also played the same game, except the table did not wobble. Results indicate that the wobbly group had higher presence and social presence with the virtual human in general, with statistically significant increases in presence, co-presence, and attentional allocation. We present the experiment and results, and discuss some potential implications for virtual human systems and some potential future studies.

Index Terms: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, Augmented, and Virtual Realities; J.4 [Computer Applications]: Social and Behavioral Sciences—Psychology

1 Introduction

Virtual humans (VHs) can sometimes assume roles of humans for purposes such as medical, military, or teacher training. They can appear in a virtual environment or can share physical space [28] during training. In general, a greater sense of presence has the potential to make training more effective, leading to the formation of teams that perform better in a real environment [12]. Lombard and Ditton define *presence* as the sense of non-mediation, which means that one perceives presence via a technological medium if totally oblivious to the existence of the medium [29]. There are many interpretations of the terms *social presence* and *co-presence*, e.g., see [10]. Goffman et al. indicate that *co-presence* exists when people sensed that they were able to perceive others and that others were able to actively perceive them [18]. Informally, just as one might think of presence in a virtual environment as a sense of "being there," one might think of co-presence with others as a sense of "being together." Blascovich et al. define *social presence* both as a "psychological state in which the individual perceives himself or herself as existing within an *interpersonal* environment" (emphasis added) and "the degree to which one believes that he or she is in the presence of, and dynamically interacting with, other veritable human beings." [9, 8]. Harms and Biocca illustrated co-presence as one of several dimensions that make up social presence, and they evaluated the validity of their social presence measures by questionnaire [22]. While there is no universal agreement on the definitions of these terms, for the purpose of this paper we adopt the Harms and Biocca perspective; *social presence* is considered to be one's sense of being socially connected with the other, and *co-presence* to be one's sense of the other person's presence.

Most research on social presence with VHs has focused primarily on the VH, e.g., its appearance [17, 40], intelligence [20, 34], and verbal and nonverbal behavior [30, 17, 1]. However, we believe the surroundings where social interactions take place also have potential for increasing social presence of VHs via incidental and indirect ways. Our expectation is that any such increase in social presence when such incidental and indirect methods are applied would be due to increased mutual awareness [18] and the shared interpersonal environment [9, 8].

Humans often engage in *direct mutual interactions* such as when shaking hands or touching each other. However, relying on such interactions to increase presence and social presence is problematic for two reasons. First, by definition, direct mutual interactions are explicit and overt, and thus may not always be appropriate for a particular real-virtual human scenario/application. Second, such interactions are typically one-time events, e.g., a handshake. Thus, if such an interaction increased social presence, the effect could fade with time. The effect (if it existed) could potentially be "refreshed" by another such interaction, but the inherent explicit/overt nature of such direct mutual interactions seems to limit their utility.

It turns out that humans also can and do engage in *indirect mutual interactions*—interactions that are *mediated* by subtle incidental movement of a common/shared object. For example, when one person hands off an object to another person, there is a short period of time when both humans are grasping the object and can feel the subtle forces exerted by each other. Or if two people are carrying a heavy piece of furniture, one might become aware of the other per-

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son's effort via incidental changes in perceived forces and weight conveyed through/by the furniture. Such interactions can occur via an even less direct path. For example, if a person sitting on the other side of a shared cubicle begins to bounce their leg against the desk (e.g., a nervous habit), one can become acutely aware of that person's presence via the vibrations transmitted through the furniture.

In this paper we determine whether such subtle incidental movement of an object that crosses the physical-virtual boundary between a real and virtual human can increase the sense of presence and social presence. Specifically we employ a real *wobbly table* that extends into the virtual world. The movement of the real and virtual parts of the table are synchronized, allowing subtle incidental interaction between real and virtual humans, as each leans on their side of the table. The wobbling is both subtle—designed to evoke some level of awareness but not necessarily an overt reaction, and naturally recurring—to continually reinforce any effects.

2 Related Work

While we are unaware of previous experiments exploring the intentional inclusion of subtle incidental movement of a physical-virtual object as a means to increase social presence, there are some areas of research that are relevant in various ways.

Interpersonal touch has been found to elicit relevant positive responses [16]. For example, the "Midas touch" refers to the phenomenon where casual touch, such as a tapping on one's shoulder, promotes altruistic behaviors and willingness to comply with one who touched [21]. Crusco and Wetzel found that a waitress who tapped lightly on customers' shoulders received larger tips than a waitress who did not touch [11]. Similar effects related to touch have been found in other studies, e.g., [13]. The effects of interpersonal touch are not limited to behavioral changes. Fisher et al. found that incidental physical contact on the palm when returning a library card made students assess the librarian more favorably [15]. Erceau and Guéguen found a similar effect with car sales people [14]. Interpersonal touch seems to hold its effects even mediated via electromechanical devices [21]. Basdogan et al. found that a haptic sensation of other participants via a shared virtual object increased the sense of togetherness [3]. Similarly, haptic feedback on a shared virtual object increased the virtual presence and social presence in a study where participants in separate physical spaces passed a virtual object in a shared virtual environment [37]. Blanke et al. [7] found the sensorimotor conflict in connection with spatial incompatibility of self-touch induced the feeling of the other person's presence.

Researchers have also explored touch interaction with social agents—physically embodied and purely virtual. Hossain et al. developed a haptic jacket to enhance interaction with VHs in the Second Life [25]. Similarly, Rahman and El Saddik developed a neck piece converting VHs kiss behavior to a tactile vibration on a user's neck [35]. A device used by Huisman et al. similarly used a vibrotactile device to convey interpersonal touch with a VH [26], however they used an augmented reality setup that could maintain visual-motor synchrony. The effects of interpersonal touch with social agents have also been investigated. Bailenson et al. found that people used less force with a VH than when they touched a non-human object, and that they touched the VH's face with less force than VH's torso [2]. They also found people used less force for female VHs than male VHs. Kotranza et al. found that a virtual patient that responded to touch was treated more like a real human [27]. Bickmore et al. found that squeezing behavior with a mannequin based virtual agent was associated with a user perception of affect arousal/valence [6]. Nakagawa et al. found that a robot with active touch encouraged motivation for a monotonous task compared to robots with a passive or no touch [32].

We believe that subtle incidental movement of a shared object crossing the physical-virtual boundary may create a form of *object extension* similar to the concept of *self extension* [19] or *virtual body ownership* [39]. As reported by Slater et al. [39], virtual limbs and bodies can come to feel like real limbs and bodies, i.e. that subjects can be given the illusion of ownership of the virtual body. One reported mechanism for inducing this illusion is via continuous *visual-motor synchrony*—the synchronous movement of the person's (hidden) real hand and a virtual hand. As reported by Groom, this effect can occur for humans inhabiting (embodying) a tele-operated robot [19]. Nishio et al. reported that even without tactile feedback, some operators felt as if they themselves had been touched [33]. Beyond the self, Belk has indicated that the *extended self* includes the self and *all objects contributing to self-identity*, including objects such as cars, pets, and musical instruments [4, 5, 24, 19]. This could in part contribute to the sense of engagement with very low-latency physical-virtual games such as "airhockey over a distance" [31] and "immersive table tennis" [36]. In a similar way, the subtle incidental movement of an object spanning a real-virtual environment could be seen as contributing to a person's self-identity, and thus act as an extension of the person into the space of the virtual human. The physical-virtual visual-motor synchrony of the object would presumably play a role in achieving and reinforcing the object (self) extension.

3 Wobbly Table Experiment

The aim of the wobbly table experiment is to examine whether subtle incidental movement of a real-virtual wobbly table can increase presence and social presence. For that purpose, we built a wobbly table spanning a real-virtual environment. The table serves as a medium by which incidental interactions with the table can be conveyed in the form of subtle table movement felt by a real and virtual human in a dyadic interaction. The table slightly wobbles depending on the weight both a real human (RH) and a virtual human (VH) put on it, and the wobbly motion in real/virtual parts of the table is synchronized.

3.1 Setting

To examine effects of subtle incidental movement of a real-virtual object in human-virtual human interaction, a VH interaction that facilitates a constrained but plausible conversation with a real user was developed. We implemented a female VH, "Katie," who could speak with a RH and perform upper-torso gestures (e.g., hand and head gestures). The VH was projected onto a screen in an office-like room as shown in Figure 1. The physical part of the table was positioned in front of the screen, creating a visual impression of facing a seated VH across the table. The physical table has a virtual counterpart that visually extended from the physical table into the (virtual) environment of the VH. The motion of physical and virtual tables were electromechanically linked to achieve visual-

Figure 1: The physical and virtual setting of the experiment with the virtual human in view.

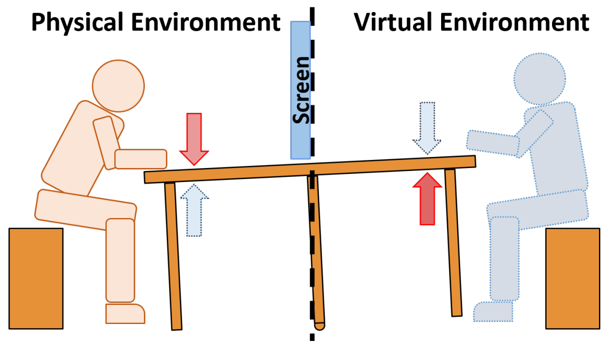

Figure 2: When a real human leans on the real side of the table, the virtual side of the table lifts up and vice versa.

motor synchrony for the subtle incidental movement of the wobbly table. The slope of the table changed subtly depending on how much weight both the virtual and real human put on the table (Figure 2). By default, the VH put both arms on the table (Figure 1), thus putting the table into a default state. The VH could apply additional weight by leaning on the table further, in turn tilting it further toward the virtual world. If the VH moved her hands off the table (Figure 3), then all forces on the table came from the participant (if any), and the table tilted accordingly.

We added office-like decorations to the physical experimental space, including a table and bookcases (Figure 1). The screen displaying the virtual world was placed on top of the table, between the bookcases. The edges of the virtual table were aligned with the physical table from the participant's viewpoint; thus, the virtual and physical parts of the table appeared to be a single table. To enable subtle wobbly movement of the table, the real side of the table was slightly lifted and anchored to pivot points on the bookcases. A handle to control pivoting was attached to the table behind the screen. Finally, a stopper was installed to enable a seesaw-like movement to the table (resulting in a maximum of 0.635 *mm* height difference at the edge of the real table). We attached a laser pointer to a leg of the table and adjusted the laser to point at a white panel on the floor about 1.5 *m* away. In this way, a change in the inclination of the real table in turn displaced the beam position on the white panel. We measured the displacement of the beam using a webcam and calculated the corresponding inclination. This calculated inclination was then applied to the virtual table, enabling synchronized movement between the real and virtual sides of the table.

3.2 Interaction Scenario

In this experiment, the participant and VH played a two-player parlor game commonly known as Twenty Questions. In Twenty Questions, one player thinks of an object but does not reveal the object to the other player (known as the guesser). The guesser then asks up to 20 yes/no questions to identify the object. If the guesser cannot identify the object after 20 questions, then he/she loses the game. The two players (virtual and real), played two games of Twenty Questions. In the first game, the participant was the guesser. These roles were swapped in the second game.

We chose the Twenty Questions game for several reasons. First, the game has been used in many studies examining social interaction, including those with virtual humans [1]. Second, with careful choices, speech in a Twenty Questions game can be constrained to reduce the chance the VH will respond awkwardly (or not at all) to the user.

We used a Wizard-of-Oz paradigm to control the VH, i.e. one of the experimenters controlled the VH using a button-GUI behind the scenes. Each button in the GUI triggered pre-recorded audio speech along with the VH's gestures corresponding to the speech. A wide range of audio/gestural responses to yes/no questions were pre-recorded. For the first round of Twenty Questions, the participant was the guesser and the object the VH was "thinking of" was a shoe. In the second round, the VH took the role of the guesser. To ensure the VH could ask plausible questions, the participant's object was pre-determined before the experiment, which was unknown to the participant. The participant chose the object by drawing lots, but the participant was not aware that all lots had the same word on them, "Smartphone." Thus, our VH could ask plausible pre-recorded questions about the object and always guessed the object correctly at the twentieth question.

3.3 Manipulations

A between-subjects design was used for this experiment. Participants were randomly assigned to either the "Wobbly" or "Control" groups described below.

- **Wobbly**: For the wobbly group, the table wobbled. The VH exhibited awareness of the table movement occasionally (two times per game) by briefly looking under the table. The VH did not verbally acknowledge awareness of the table movement.

- **Control**: For the control group, the table was fixed (did not wobble), and the VH did not exhibit any reactions to the table.

In both groups, participants played the two games of Twenty Questions with the VH until completion. Note that the participant could guess the object fairly early in the first round. Thus, the interaction duration was not predefined.

3.4 Hypotheses

We formulated the following two general hypotheses:

- **[Presence]** Participants in the wobbly group will report higher presence in the mixed environment than participants in the control group.

- **[Social Presence]** Participants in the wobbly group will report higher social presence with the VH than participants in the control group.

3.5 Measures

We measured presence and social presence primarily with a combination of post-experiment subjective surveys. We used the presence questionnaire by Witmer and Singer [42] and the social presence questionnaire by Harms and Biocca [22]. Both of these surveys are widely recognized as valid measures and have been used in many experiments. Since the study setup had both real and virtual components (mixed reality), questions specific to virtual-only interactions were removed from the Witmer and Singer questionnaire. We also measured social presence indirectly through questionnaires that assessed two possible correlates of high social presence, affective attraction (or liking) [23] and anxiety [41]. Lastly, participants provided informal comments on the interaction verbally and on paper.

3.6 Participants

We recruited participants within our university community including students, staff, and faculty. Twenty undergraduate and graduate students participated in the experiment (9 females, 11 males, mean age: 22.9, age $SD = 3.45$, age range: 18–33 years). All participants received fifteen dollars for their participation (duration: 30–60 min).

Figure 3: Example gestures used by the Virtual Human. Our VH's basic posture was placing both arms on the table. During the Twenty Questions games, the VH used various gestures, e.g, raising both arms, leaning on the table and writing, and checking the table legs. Raising both arms gestures (left) and leaning on the table gesture (center) triggered wobbling of the table. Occasionally, the VH looked down at the table leg, ostensibly looking for the reason for the table's wobble (right).

3.7 Procedure

When participants arrived, we guided them to the questionnaire area. They were asked to read and sign the informed consent and fill out a demographics questionnaire. We explained that they would play a couple of Twenty Questions games with a VH. We briefly described the rules of the game, and the participants were asked to pick a card from a card deck, which had the object name written on the other side (all cards said "Smartphone"). Before entering the experimental space, we asked them to write the answers for the 4th, 8th, 12th, and 16th questions during each game on a piece of paper taped to the wobbly table. This ensured participants would put weight on the table and experience subtle incidental movement. The participants were also informed that they would be the guesser for the first game, and then the VH would be the guesser in the second game. After video/audio recording started, participants entered the experimental space and played Twenty Questions with the VH. Once the participants completed both games, we guided them out of the room, and asked them to fill out post-questionnaires. After the questionnaires, the experiment ended.

4 Results

4.1 Presence

We used a seven-point Likert-scale for the presence questionnaire by Witmer and Singer [42]. These questions were originally designed and tested for use in purely virtual environments. Since our wobbly table setup was not a purely virtual environment, we excluded certain inappropriate questions (e.g., questions about navigation). The aggregate presence score was calculated by averaging all responses in the questionnaire. An independent-samples t-test was conducted to compare the presence scores in the control and wobbly groups, and there was a significant difference in the scores for the control ($M = 4.52$, $SD = 0.39$) and the wobbly ($M = 4.95$, $SD = 0.42$) groups; $t(18) = -2.396$, $p = 0.028$. (See Figure 4, Table 1 and 2 for detailed results).

Table 1: Independent-samples T-test on Presence and Sub-factors

	t	df	p	Cohen's d
Presence	-2.396	18	0.028	-1.072
Control Factor	-2.366	18	0.029	-1.058
Sensory Factor	-2.871	18	0.01	-1.284
Distraction Factor	0.596	18	0.559	0.267
Realism Factor	-1.552	18	0.138	-0.694

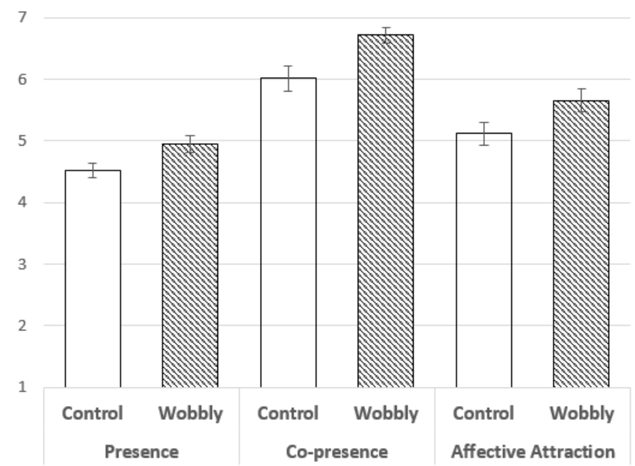

Figure 4: Means of Presence, Co-presence, and Affective Attraction scores for each group. Presence and Co-presence scores were significantly larger in the wobbly group. (Error bars represents standard error). These scores are aggregates, calculated by averaging.

4.2 Social Presence

We used the social presence questionnaire by Harms and Biocca, in which social presence was conceptualized as six sub-dimensions: co-presence, attentional allocation, perceived message understanding, perceived affective understanding, perceived affective interdependence, and perceived behavioral interdependence [22]. Each question in the questionnaire was on a seven-point Likert-scale, and

Table 2: Presence and Sub-factors Descriptives

	Group	N	Mean	SE
Presence	Control	10	4.52	0.123
	Wobbly	10	4.953	0.133
Control Factor	Control	10	4.114	0.189
	Wobbly	10	4.757	0.195
Sensory Factor	Control	10	4.975	0.222
	Wobbly	10	5.775	0.169
Distraction Factor	Control	10	4.167	0.273
	Wobbly	10	3.933	0.28
Realism Factor	Control	10	5.1	0.272
	Wobbly	10	5.65	0.227

Table 3: Independent-samples T-tests on Social Presence Sub-dimensions

	t	df	p	Cohen's d
Co-presence	-2.868	18	0.010	-1.283
Attentional Allocation	-2.224	18	0.039	-0.995
Message Understanding	-0.608	18	0.551	-0.272
Affective Understanding	-0.099	18	0.922	-0.044
Emotion Interdependency	0.186	18	0.855	0.083
Behavior Interdependency	-1.552	18	0.138	-0.731

Table 4: Social Presence Sub-dimensions Descriptives

	Group	N	Mean	SE
Co-presence	Control	10	6.017	0.21
	Wobbly	10	6.717	0.124
Attentional Allocation	Control	10	5.317	0.268
	Wobbly	10	6.033	0.179
Message Understanding	Control	10	5.8	0.155
	Wobbly	10	5.933	0.156
Affective Understanding	Control	10	4.033	0.386
	Wobbly	10	4.083	0.323
Emotion Interdependency	Control	10	3.5	0.304
	Wobbly	10	3.4	0.445
Behavior Interdependency	Control	10	4.317	0.23
	Wobbly	10	5	0.35

Table 5: Independent-samples T-test on Affective Attraction

	t	df	p	Cohen's d
Affective Attraction	-2.035	18	0.057	-0.91
Unpleasant-pleasant	-1.686	18	0.109	-0.754
Cold-warm	-1.709	18	0.105	-0.764
Negative-positive	-0.277	18	0.785	-0.124
Unfriendly-friendly	-1.555	18	0.137	-0.695
Distant-close	-1.8	18	0.089	-0.805

Table 6: Affective Attraction Descriptives

	Group	N	Mean	SE
Affective Attraction	Control	10	5.12	0.191
	Wobbly	10	5.66	0.184
Unpleasant-pleasant	Control	10	5.5	0.269
	Wobbly	10	6.1	0.233
Cold-warm	Control	10	5.2	0.2
	Wobbly	10	5.7	0.213
Negative-positive	Control	10	5.7	0.213
	Wobbly	10	5.8	0.291
Unfriendly-friendly	Control	10	5.5	0.269
	Wobbly	10	6.1	0.277
Distant-close	Control	10	3.7	0.396
	Wobbly	10	4.6	0.306

we averaged participant responses to construct each sub-dimension score. We conducted independent-samples t-tests to compare the six sub-dimensions across the control and wobbly groups, and found statistically significant differences in the co-presence sub-dimension ($M = 6.02$, $SD = 0.66$ for control group; $M = 6.72$, $SD = 0.39$ for wobbly group) and the attentional allocation sub-dimension ($M = 5.32$, $SD = 0.85$ for control group; $M = 6.03$, $SD = 0.18$ for wobbly group) (See Figure 4, Table 3 and 4 for detailed results).

4.3 Affective Attraction and Anxiety

We used the affective attraction items from [23] to measure the participants' attraction to the VH. The five sub-items were rated on a seven-point Likert-scale. We averaged all items to construct an aggregate affective attraction score. We conducted independent-samples t-tests on the both the aggregate and individual scores. Although there were no significant differences between groups, there appears to be a trend on the affective attraction score ($t(18) = -2.04$ and $p = 0.057$); that is, participants in the wobbly group felt more attraction for the VH than participants in the control group (See Figure 4, Table 5 and 6 for detailed results).

The anxiety questionnaire [41] was a single question "How did your interaction with the other player (Katie) make you feel?", followed by a list of anxiety subdimensions participants rated on a scale of 0 to 10, where 0 was "Not at all" and 10 was "Extremely Strong". We conducted independent-samples t-tests on each question in the control and wobbly groups. Participants in the wobbly group felt less "In control", however they all rated their desire to leave as zero. (See Table 7 and 8 for detailed results).

5 Discussion

Here we discuss the experimental results in the context of presence and social presence, and speculate about potential causes and implications, in view of some relevant related work.

Presence: The wobbly group participants' perceived level of presence was (statistically) significantly higher than the control group's in our mixed reality wobbly table setup, which supports our presence hypothesis (see Section 3.4). In particular, the mean scores for two sub-factors of presence, the "Control Factor (related to one's ability to control the surrounding environment)" and the "Sensory Factor (related to movement perception and sensory modalities to perceive the environment)," were higher for the wobbly group. The increase in the "Control Factor" could be a consequence of the wobbly participant's ability to exert control, however subtle, over the virtual side of the table. We note that the movement of the wobbly table was recurring during the interaction; so, the wobbly group's sense of the link between real and virtual spaces could be reinforced each time the table wobbled, and perhaps by extension, their sense of control over the virtual space could be maintained/enhanced without collapse. The higher "Sensory Factor" could result from the positive effect of the additional haptic feedback experienced by participants in the wobbly group, especially combined with the visual-motor synchrony when the table moved. As we introduced in Section 2, the visually synchronized real-virtual table movement with subtle haptic feedback could induce an illusion of the object (self) extension, and this illusion might play a role in increasing presence in the wobbly group—similar to how virtual body-ownership can enhance one's sense of presence in a virtual environment. Although there was latency between the movement of the real and the virtual table, the latency (200 *ms* in our wobbly table setup) was ignorable to achieve one's illusion of visual-motor synchrony and object extension based on the findings from other previous literature, e.g., a rubber hand illusion occurred when the delay between visual and tactile sensations was less than 300 *ms* [38], and Mueller et al. reported 250 *ms* delay was tolerable in a physical-virtual airhockey game [31].

Social Presence: With respect to social presence, we hypothesized that the wobbly group's perceived social presence with the VH would be higher than the control group's (see Section 3.4). The results showed that there were significant differences in co-presence and attentional allocation between the groups. The reasons for the significant differences might be the increased mutual

Table 7: Independent Samples T-test on Anxiety Questionnaire

	Assumption	t	df	p	Cohen's d
Anxious	equal var.	-1.833	18	0.083*	-0.82
	not assumed	-1.833	13.515	0.089	-0.82
Excited	equal var.	-1.658	18	0.115	-0.742
	not assumed	-1.658	14.638	0.118	-0.742
Tense	equal var.	-0.461	18	0.65	-0.206
	not assumed	-0.461	17.465	0.65	-0.206
Alert	equal var.	-0.82	18	0.423	-0.367
	not assumed	-0.82	17.856	0.423	-0.367
In	equal var.	2.882	18	0.01*	1.289
Control	not assumed	2.882	12.74	0.013	1.289
Desire	equal var.	3.597	18	0.002*	1.609
to Leave	not assumed	3.597	9	0.006	1.609

*Levene's test is significant ($p < .05$), suggesting a violation of the equal variance assumption

Table 8: Anxiety Questionnaire Descriptives

	Group	N	Mean	SE
Anxious	Control	10	1.6	0.452
	Wobbly	10	3.4	0.872
Excited	Control	10	6.1	0.674
	Wobbly	10	7.4	0.4
Tense	Control	10	2.3	0.831
	Wobbly	10	2.8	0.696
Alert	Control	10	4.9	0.9
	Wobbly	10	5.9	0.823
In Control	Control	10	7.3	0.367
	Wobbly	10	4.8	0.786
Desire to Leave	Control	10	1.7	0.473
	Wobbly	10	0	0

awareness and the tightly shared interpersonal space via the wobbly table and the VH's reactive behaviors (looking under the table) despite of the wobble table's subtle and incidental movement. This interpretation is along with our expectation in Section 1—one's perceived mutual awareness and the shared interpersonal environment could be the factors to increase the level of social presence. The increased sense of presence previously discussed might also encourage the wobbly group's awareness of the shared space, and it could establish the mutual awareness in association with the VH's awareness of the shared space. While interpreting the results, we realized that our wobbly table setting might be more beneficial to encourage three particular sub-dimensions of social presence: co-presence, attentional allocation, and behavior interdependency, rather than the other sub-dimensions because the manipulations in the study were more related to visual/behavioral changes (i.e., visually synchronized wobbly table and the VH's reactive behaviors to the wobbly movement), which we think possibly affected the above three sub-dimensions. The other sub-dimensions: message/affective understanding and emotional interdependency seemed more associated with verbal communication or detailed facial expressions, which we did not adjust in our setting. Although the behavior interdependency sub-dimension did not show a significant difference, we could observe noticeably higher responses for the wobbly group than the control group similar to the responses in co-presence and attentional allocation, so might be able to see a significant difference if the sample size was large enough.

With regard to affective attraction, which we used as indirect measures for social presence, we did not see any significant differences between groups, but participants for the wobbly group rated the VH more positively in all affective attraction questions (e.g., pleasant, warm, and friendly). There could be various reasons for this result, but we speculate that the interpersonal touch—the subtle and incidental haptic sensation via the wobbly table—could be one of the reasons considering the previous observations, e.g., interpersonal touch altered one's assessment of the other person or a virtual agent more positively [6, 14, 15]. This subtle interpersonal touch via the wobbly table might also result in the lower desire to end the social interaction (playing Twenty Questions) with the VH in the anxiety questionnaire, as a robot with active touch encouraged motivation for a monotonous task in [32].

6 Conclusions and Future Work

We examined the effects of subtle incidental movement of a real-virtual table on social presence during a conversational task. Specifically, we developed a scenario where a real human (RH) and a virtual human (VH) carried out a conversational task while seated at a table that spanned the physical-virtual space—i.e. the table included a physical half and a virtual half. We configured the physical (half) table so that it could tilt slightly toward/away from the subject, and tracked the tilting to ensure the virtual half (rendered) would move in synchrony with the physical half. We conducted a user study where the primary task involved participants interacting with the VH via a game of "Twenty Questions." We used a Wizard of Oz paradigm to control the VH, with pre-recorded audio and corresponding gestures triggered by a GUI. For one group of participants, the table wobbled and the VH showed awareness of the wobbles, while in the control group the table was fixed and the VH did not show any awareness of the wobbles. We employed pre- and post-questionnaires to assess the effects. Subjects sharing a wobbly table with the VH exhibited a general increase in presence and social presence, with statistically significant increases in presence, co-presence, and attentional allocation. In addition, subjects in the wobbly group showed more affective attraction for the VH.

In the near-term we plan to further refine our experimental conditions to identify which sub-factors appear to contribute more/less to the observed effect. For example, we are interested in the role of the haptic and tactile sensations, the effects of visual-motor synchrony between the real and virtual table, and the effects of the VH's overtly exhibited awareness of the wobbling.

More broadly our goal is to explore peripheral (indirect, incidental, etc.) mechanisms for increasing social presence with virtual humans. The idea is that such mechanisms, if subtle or naturally occurring, could go unnoticed by users and thus be employed without affecting the primary interaction tasks. If logistically practical, the mechanisms could be integrated more widely into various applications. For example, it might be possible to increase social/co-presence with a virtual patient if a physical-virtual patient bed shifted with the patient's body movements, or conversely if movement of the bed caused the patient to react. Or it could be that social/co-presence would increase if a VH reacts to intentionally added (unnecessary but useful) sounds emanating from behind the RH. In the long term we hope to develop a suite of subtle mechanisms that others could add to VH scenarios to immediately make an impact on the user's sense of social presence, and by extension, improve applications where social presence is critical to success.

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