Injecting Nonverbal Mimicry with Hybrid Avatar-Agent Technologies: A Naïve Approach

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ABSTRACT

Humans communicate to a large degree through nonverbal behavior. Nonverbal mimicry, i.e., the imitation of another's behavior can positively affect the social interactions. In virtual environments, user behavior can be replicated to avatars, and agent behaviors can be artificially constructed. By combining both, hybrid avatar-agent technologies aim at actively mediating virtual communication to foster interpersonal understanding and rapport. We present a naïve prototype, the "Mimicry Injector", that injects artificial mimicry in real-time virtual interactions. In an evaluation study, two participants were embodied in a Virtual Reality (VR) simulation, and had to perform a negotiation task. Their virtual characters either a) replicated only the original behavior or b) displayed the original behavior plus induced mimicry. We found that most participants did not detect the modification. However, the modification did not have a significant impact on the perception of the communication.

CCS CONCEPTS

• **Human-centered computing** → *Interaction paradigms*; *Virtual reality*; *Empirical studies in collaborative and social computing*;

KEYWORDS

Virtual Reality; Hybrid Avatar-Agent Technology; Social Interaction; Nonverbal Behavior; Mimicry

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1 INTRODUCTION

In everyday social interaction, humans communicate to a large degree through nonverbal behavior [20] and adaptive behavioral processes that form our social interactions [32]. Research has begun to investigate and interpret these behaviors through novel methods [6] and social signal processing [34]. The detection of such behaviors, in turn, can be used to trigger the behavioral reactions of virtual agents [14].

However, these behavioral modifications could also be used in real-time mediated communications in embodied, immersive social interactions. As motion sensing technologies become available to consumers, VR simulations and spacial user interfaces of today allow replicating a large amount of nonverbal behaviors to avatars [31]. As the behavioral data is accessible, these simulations have the potential to decouple the physical behavior from the visual information presented to the users [2], and in consequence to modify the behavioral data stream and thus the behavior that is displayed to a communication partner. VR applications for social interaction may therefore not only serve as passive transmitters of communication, replicating the behavioral data of users, but become an adaptive tool, actively modifying and adapting behaviors in interpersonal encounters by utilizing hybrid avatar-agent technologies and underlying social artificial intelligence [29]. The applications could be manifold. Such systems could for example foster the inclusion and training of people with social disorders that have difficulties to express and interpret nonverbal behaviors [10] and could be of great help to further understand differences in behaviors [12]. Furthermore, such systems could support inter-cultural communications and transform culture-specific behavior and cues to foster understanding not limited to human-agent interactions [18], but human-human interactions mediated by hybrid avatar-agent technologies.

In this paper, we investigate a hybrid prototype capable of modifying upper body motion, by utilizing the phenomenon of nonverbal *mimicry* in a naïve approach. Our focus was the prototypical implementation of the simulation, the modification, and the blending process. We evaluated the simulation with a dyadic user study, investigating the detection rate, and the impact on the conversation.

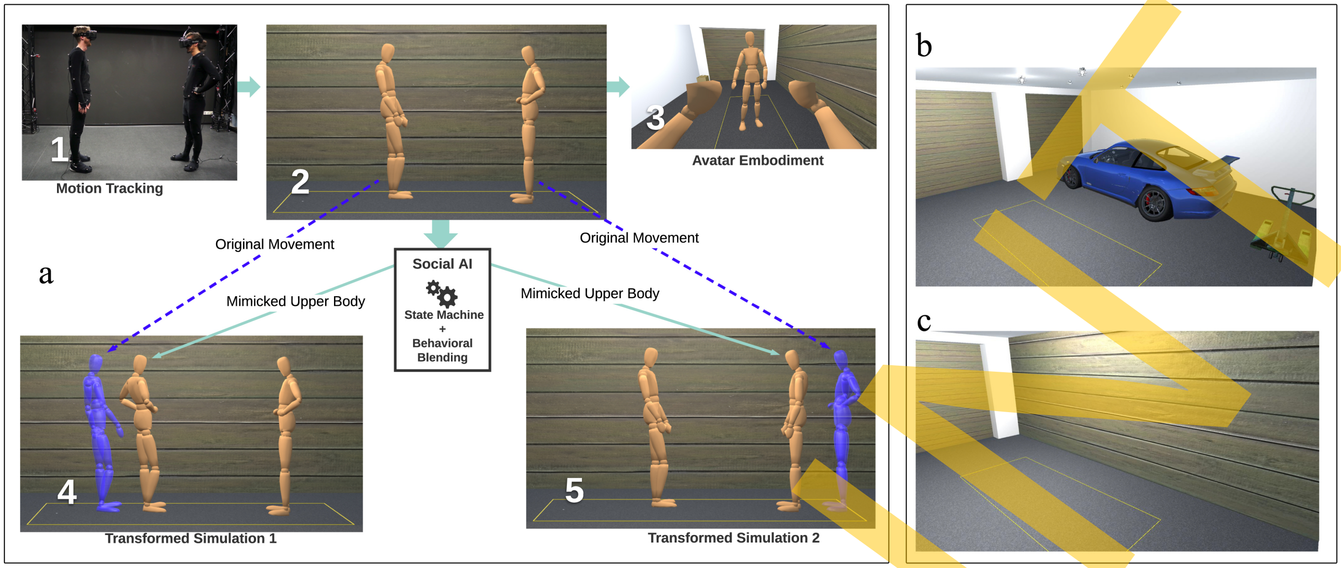

Figure 1: a) Functional principle. Position differences were introduced for illustration purposes. b) Simulation during the VR acclimatization in the study. c) Simulation during the negotiation in the study.

2 RELATED WORK

Nonverbal or motor mimicry can be described as the motor imitation of another's physical behavior in social interaction [9], such as adapting a certain pose or distinct limb positions. Also referred to as the "chameleon effect" [19], nonverbal mimicry was conceptualized as a reflex based on cues previously experienced, such as the perception of an emotional expression or a cognitive operation (e.g., perspective-taking), and was shown to serve not only as informative but also communicative act in social interaction [5]. Mimicking others' behaviors can facilitate affiliation, rapport, and liking [9]. Similarly, being mimicked was shown to facilitate liking and rapport [4], and empathy [21]. Vice versa, perceiving rapport and liking leads to more mimicry [22, 33].

Multiple previous works have investigated aspects of virtual mimicry ("digital chameleons") [3] and virtual rapport [14, 15] focusing on human-agent interactions [7, 11, 14–16]. Further works investigated the real-time modification of facial expressions [8, 24] using desktop scenarios, as well as the visual augmentations of social phenomena in multi-user VR interactions [27]. To our knowledge, the injection of artificial mimicry by modifying body movement in immersive, embodied, real-time virtual interactions is not yet investigated. To fill this gap and further explore the potential of hybrid technologies, we constructed a naïve hybrid avatar-agent system. The "mimicry injector" periodically modifies the body motion of two interactants.

3 SYSTEM DESIGN AND IMPLEMENTATION

Based on previous work [30], our apparatus used a 16 camera system (OptiTrack, Flex3, 100 Hz) to perform body tracking (see Fig. 1) and synchronously streaming the data to two client simulations that are not network dependent. We developed a Unity3D simulation in which users can be embodied as avatars, which is rendered to Oculus DK2 head-mounted displays (HMDs) (see Fig. 1). The motion-to-photon latency was approximated to 90ms using video-based measurements. We fuse the relative orientation data of the HMD inertial measurement unit with the absolute coordinates of the tracking system to increase frequency and reduce the latency of the first person perspective rendering and sickness effects.

3.1 Artificial Injection of Nonverbal Mimicry

The joint transformation data (skeleton data) provided by the tracking system is used to drive faceless wooden mannequin avatars representing each user, uniformly adapted in their scale according to the participants' height. A state machine controls the injection of nonverbal behavior mainly based on four states and included two states to extend the principle in future work, see Fig. 2. The idle state simply replicates the original physical movements. After 20 seconds, the start mimicry blending state is activated. The state blended the original upper body (excluding hips) motion of the partner's skeleton model to one's own buffered (three seconds delay) upper body motion using a smooth linear interpolation over two seconds. After the blending, the inject mimicry state (8s) and wait for injection end state (1s) are held to inject mimicry for a total of 9 seconds. Vice versa, the buffered own motion represented on the partner's avatar is then blended back to the partner's original motion in a two second frame, after which the state changes to the idle state again for 20 seconds, and so on.

4 METHODS

4.1 Design

In a between-subjects design (mimicry injection vs. control condition), we evaluated the functionality of the prototype and its impact on the social interaction using a roleplay task. In both conditions, participants saw their own physical behavior replicated to their

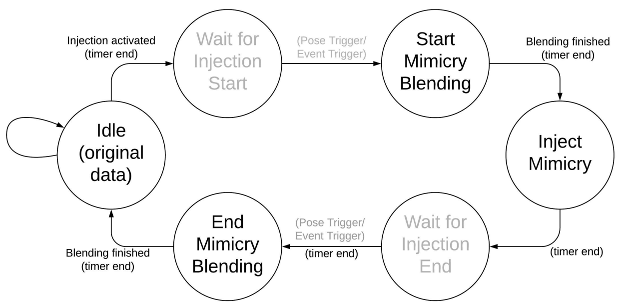

Figure 2: Mimicry injection principle. The grayed out states were introduced for future developments, e.g. to stop the mimicry injection based on speaker/listener status.

own avatar. In the mimicry injection condition, the visual representation of the partner's behavior was modified with the "mimicry injector".

4.1.1 Procedure. Participants were shortly introduced to each other, presented a consent form, and a pre-study questionnaire assessing demographics. After applying capture suits and 37 markers, participants were given written instructions about their role (buyer/seller) that included three arguments which they could present to strengthen their position in the negotiation (e.g., that the axis is broken, which was later visible on the simulated car). The participants were then equipped with the HMDs and guided to predefined start positions. The system was calibrated, and the simulation started. At the beginning of each trial, we presented the environment and the car which served as VR acclimatization phase and to control for their impression of the object. After one minute, a garage door blocked the view of the car. Participants were asked to turn to each other and start the negotiation, see fig.1 b, c. In the mimicry condition, we excluded the first 20 seconds from the injection and stopped the injection when they found a consensus, as participants typically shake hands at these times. During the simulation, a yellow square marked safe tracking area to avoid collisions with the physical environment, see figure 1 b, c. When participants found a consensus or the 7 minute time window was up, the simulation was stopped. Participants were then asked to answer a post-experimental questionnaire that assessed dependent measures, followed by the debriefing, and the compensation.

4.1.2 Dependent Measures. In the post-experimental measure, we asked participants to judge whether the partner's behavior was realistic (1=do not agree at all, 7=fully agree). We further assessed factors for social and co-presence using the questionnaire from [23] (1=do not agree at all, 7=totally agree, Cronbach's αs> .649) as well as a measure for virtual rapport using the questionnaire from [13] (1=do not agree at all, 7=totally agree, α = .807). We also included a measure for liking and attraction adapted from [25] (1=do not agree at all, 7=totally agree, α = .903). We assessed affect with the positive and negative affect scales [35] (1=little or none, 5=extreme, αs> .813). We tested how the manipulation impacts trust with three questions (e.g., "I would rely on my communication partner", 1=does not apply at all, 7=totally applies, α = .856). We further assessed if participants reached a consensus, and how long it took them to negotiate for this consensus (stopwatch) and calculated the difference in interpersonal distance over time. Furthermore, participants were asked to comment on the behavior of the other person and their suspicion.

4.1.3 Control Measures. To control for a bias introduced through personality traits or the previous relationship, we measured the social-closeness index [1] (1=not close at all, 7=very close), and a measure of the Big 5 personality traits [26]. Simulator sickness [17] was measured in a pre-post measure.

4.1.4 Participants. From the 70 student participants who took part in the study, we excluded dyads with participants who experienced technical problems, who did not have fluent language skills, or who did not fulfill the task. Participants were blind to the goal of the experiment. One dyad was excluded because a participant had a correct suspicion. Our final sample consisted of 40 German participants (24 females, M_{age} = 21.87, SD_{age} = 2.54) equally distributed amongst conditions.

5 RESULTS

5.1 System Evaluation

We excluded two dyads from the technical analysis due to corrupt data. Data analysis showed that mimicry was injected 25.44 % of the overall conversation time (SD = 1.98 %). On average, 8.39 (SD = 3.13) mimicry injections took part during a conversation in the mimicry condition. However, only two comments regarding the behavior from participants in the mimicry condition mentioned that they felt that their partners adapted their movements (e.g., "made similar movements than I did"). Thus, we evaluate the technical functionality as rather successful.

5.2 Control Measures

T-tests assessing differences for the control measures revealed that differences where non-significant. ANOVA results for simulator sickness in a pre-post measure showed that subjects felt sicker (p < .001) after the exposure but there was no significant difference between the conditions.

5.3 Dependent Measures

T-tests for behavioral realism, social-presence, co-presence, as well as the rapport measure did not yield to significant results. Neither the trust rating nor the interpersonal attraction or positive/negative affect yielded to significant differences between the conditions. Fig. 3 depicts the subjective results. Overall, 8 out of 10 dyads found a consensus in the control condition, and 6 out of 10 in the mimicry condition. A chi-square test showed that the difference was not significant. 6 out of 8 male dyads and 8 out of 12 female dyads reached a consensus. The difference was not significant. The time participants interacted was slightly longer in the mimicry injected condition (M = 327.5 s, SD = 108 s), compared to the non-mimicry condition (M = 284.8 s, SD = 82.89 s). T-tests showed that neither the total interaction time, the negotiated price, the time to consensus, or the difference in interpersonal distance from the start of the interaction to the end of the interaction differed significantly between the conditions (see Tab. 1).

Table 1: Results of the objective measures

	Control		*Mimicry Injected*	
Measure	M	SD	M	SD
Interaction time [s]	251	48	265	97
Negotiated price [€]	35000	1793	36217	1068
Time to consensus [s]	251	48	266	97
Distance (start-end) [cm]	-24	188	+21	436

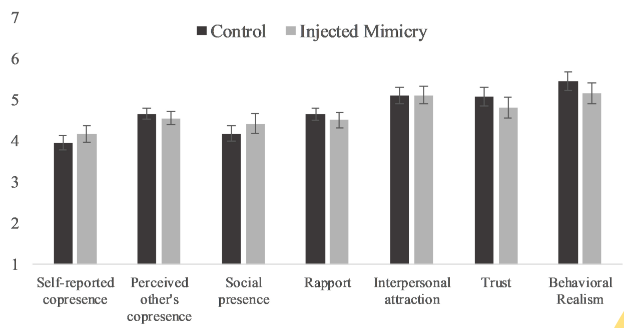

Figure 3: Results of the subjective dependent measures. Error bars denote the standard error mean.

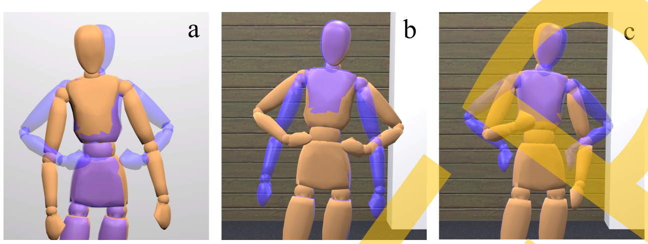

Figure 4: Modification examples. Blue transparent avatar: original user motion. Wooden mannequin: modified motion presented to the partner. a) First person view of participant X showing a successful adaptation of the original pose of participant Y, and (b) vice versa. c) Mimicked dialog gesture that might have a negative impact on rapport perception and disrupt nonverbal synchrony.

6 DISCUSSION AND FUTURE WORK

While the results show no direct impact on the perception of the communication, we evaluate the prototype as rather successful. One subject identified the manipulation and had a correct suspicion, and only two subjects consciously notified the modification. We aim at investigating blending techniques further.

Regarding the impact on the perception as such, our naïve periodic injection of mimicry leads to the mimicking of body poses, but also of specific dialogue gestures accompanying speech. Thus, these replications may have had a mirroring appearance, but not on a semantic level, see Fig. 4. Furthermore, the asynchronous simulations lead to the fact that both partners had overlapping mimicry inductions in the simulation. These may have impacted the impressions contra-productively, as entrainment processes of interpersonal synchrony are bi-directional, time-dependent processes, similar to rhythm and instrumental interplay in music. Thus, the injection at random points during the communication may have disrupted processes of coordination and synchronization.

Thus, future improvements should include distinct triggers for the injection, such as detecting the speaker and listener of the conversation [28], which implies a networked simulation that includes additional modalities such as voice or gaze. Attentional focus is of importance for a second reason, that is, the injection is not necessary or cannot be detected when the communication partner looks in another direction or focuses on other objects in the scene. In our study, this was prevented as the partners had a narrow scenario and did not have many other objects to focus on. However, in future applications for collaborative and social interaction, this might not necessarily be the case.

Also, there is no doubt that the verbal channel is of high importance for communication in most social interactions. Considering that our study was based on a strong verbal exchange, we can therefore not rule out that the verbal channel had an overruling impact on the outcome. However, we argue that everyday social interaction is mostly accompanied by verbal exchange in addition to nonverbal behavior.

Another improvement to the social AI triggering modifications could be a semantic judgment to detect complex gestures, and prevent the injection of movements that are not suitable for the injection. Furthermore, a "status analysis" judging the current rapport and the conversational situation in real-time could assess the necessity of modifications and prevent inadequate injections that could happen with our naïve system, as it that acts periodically.

Observing the simulation, we noticed slight "foot-skating" issues, due to the kinematic retargeting applied, which could have had a negative bias. Furthermore, we did not test how using more realistic avatars would impact the results. Finally, our results cannot be blindly generalized as the sample size in our study was limited.

7 CONCLUSION

We presented a system to inject nonverbal mimicry into embodied social interactions in VR. To our knowledge, we are the first to follow this approach. Our evaluation showed successful results with regards to the technology and functionality, but improvements have to be made regarding the underlying social artificial intelligence, as the "secret code of nonverbal communication" has to be respected. The application gives first insights and can act as a research platform, not only for further developments but also to better understand human behavior as such. Future work could bring a more comprehensive understanding of the benefits of such techniques. Without a doubt, the way we communicate through media will change. Despite the potential of hybrid technologies, ethical debates have to be initiated to discuss benefits and risks that arise from behavioral sensing, transmission, and modification.

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