Persuaded by the Machine: The Effect of Virtual Nonverbal Cues and Individual Differences on Compliance in Economic Bargaining

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Declarations of interest: none

Abstract

Receiving a touch or smile increases compliance in natural face-to-face settings. It has been unclear, however, whether a virtual agent's touch and smile also promote compliance or whether there are individual differences in proneness to nonverbal persuasion. Utilising a multimodal virtual reality, we investigated whether touch and smile promoted compliance to a virtual agent's requests and whether receiver's personality modulated the effects. Compliance was measured using the ultimatum game, in which participants were asked to either reject or accept an agent's monetary offers. Decision-making data were accompanied by offer-related cardiac responses, both of which were analyzed as a function of expression (anger, neutral, and happiness), touch (visuo-tactile, visual, no touch), and three personality traits: behavioral inhibition/activation system sensitivity (BIS/BAS) and justice sensitivity. People accepted unfair offers more often if the agents smiled or touched them. The effect of touch was more enhanced in those with low justice sensitivity and BAS, whereas facial expressions affected those with high BIS the most. Unfair offers amplified the cardiac response, but this effect was not dependent on nonverbal cues. Together, the results suggest that virtual nonverbal behaviors of virtual agents increase compliance and that there is substantial interindividual variation in proneness to persuasion.

Keywords: interpersonal touch, facial expression, compliance, decision-making, virtual agent

1 Introduction

Facial expressions and body gestures convey valuable information about another's feelings and intentions (Ames & Johar, 2009, Van Kleef, De Dreu, & Manstead, 2010). While our tendency to rely on nonverbal behaviors is important in successfully navigating social life, this dependency can also be exploited (e.g., Fisher, Rytting, & Heslin, 1976; Vrugt, 2007). That is, sometimes a warm smile does not reflect the sender's feelings toward the receiver but is used deliberately to gain compliance. As an example of the persuasive influence of facial cues, Vrugt (2007) showed that people entering a shopping area were more likely to sign a petition promoting animal welfare if the request was accompanied by a reciprocal smile. The persuasive power is not limited to faces, however, but is also apparent in physical contact (Gallace & Spence, 2010). Demonstrating the so-called Midas touch effect, Crusco and Wetzel (1984) found that waiters who touched their customers during the service got larger tips than those who did not make physical contact.

Touch and smile promote compliance because they establish interpersonal connectedness and liking (Montagu & Matson, 1979). However, recent studies have shown that the persuasiveness of such affiliative behaviors even occurs in online settings (Haans, de Bruijn, & IJsselsteijn, 2014; Mussel, Göritz, & Hewig, 2013). For instance, replacing physical contact with computer-mediated electromechanical vibrations still evokes the Midas touch effect, as demonstrated in a recent study by Spapé et al. (2015). Spapé and colleagues had individuals play repeated rounds of the ultimatum game (Güth, Schmittberger, & Schwarze, 1982) with non-collocated opponents and showed that participants were more prone to being generous and accepting unfairness after receiving a vibrotactile touch from their co-player. Similarly, but with regard to facial expressions, Mussel and colleagues (2013) found that people were more likely to agree to financial propositions from another human if the offers were mediated by a smiling virtual character.

The power of nonverbal persuasion may thus extend to computer-mediated communication, but what happens to the effect of nonverbal cues when humans encounter an embodied virtual agent that is not guided by a human but by an algorithm? According to the emotions as social information model (Van Kleef et al., 2010), nonverbal behaviors influence our decisions because they convey valuable information regarding the other person's mental state and intentions. Therefore, if an agent is known to have no intentions, beliefs, or mental states, one should assume little or no persuasive influence due to the expressions. However, the empirical evidence suggests a different conclusion (e.g., de Melo, Carnevale, & Gratch, 2011; Ravaja, Bente, Kätsyri, Salminen, & Takala, 2016). As an example, in a study by Ravaja and colleagues (2016), participants played the economic bargaining game called the prisoner's dilemma with two algorithm-guided virtual agents. Before each decision, the agent showed an emotional facial expression. People were found to collaborate less with agents showing angry facial expressions than those expressing sadness, joy, or neutrality.

People thus seem to apply the social heuristics of natural, interpersonal interaction to machines that mimic social features (e.g., facial expressions) (see also Reeves & Nass, 1996). This does not, however, mean that our emotional reactions to humanlike machines and humans are exactly the same. While people cooperate more with virtual agents that display cooperative facial expressions (e.g., smile after cooperation) than those that do not, this effect is much stronger if the agent is thought to be controlled by another human (de Melo, Gratch, & Carnevale, 2015). Therefore, the social influence is strongly dependent on the level of agency attributed to the agent (de Melo et al., 2015). According to Blascovich et al. (2002), a multitude of social cues, such as the agent's appearance, movements, emotional expressions, and sense of presence, contribute to the agent's influence on a user's social behavior. For this reason, Blascovich et al. (2002) saw VR as a particularly useful methodological tool for investigating social influence because it allows a mundane visual experience and a high sense of presence in the projected environment.

Rapid progress in VR technology has taken place since Blascovich and colleague's manifesto on VR-based social psychological research. For example, recent developments in 3D graphics, head-mounted displays, and haptic technology now allow presentation of virtual agents that not only look realistic and express emotions on their face but are also able to touch the user via haptic devices (e.g., Ravaja, Harjunen, Ahmed, Jacucci, & Spapé, 2017). The benefits of such visceral face-to-face interaction can be substantial for health care, education and advertisement as these interaction contexts typically involve persuasive communication of some sort. Currently, conversational agents as chatbots are becoming popular in therapy and education (Nutt, 2017, Song, Oh, & Rice, 2017), and may soon substitute parts of other textual interfaces (Klopfenstein, Delpriori, Malatini, & Bogliolo, 2017). Replacing these simple textual interfaces with VR-based embodied virtual agents or robots may further enforce social influence of these systems (e.g., see Provoost, Lau, Ruwaard, & Riper, 2017). Here, understanding the role of affective nonverbal cues will be crucial.

Given that previous research on computer mediated non-verbal persuasion builds solely on unimodal non-immersive communication technologies, such as 2D presentations of agent expressions (e.g., de Melo et al., 2011; Ravaja et al., 2016), the scientific knowledge about the potential of non-verbal persuasion in immersive VR remains scarce. One aspect that remains completely unexplored is the degree to which individual differences determine persuasiveness of computer's non-verbal cues. It is likely that some people are more prone to the persuasive non-verbal influences than others, and that individual differences in emotional reactivity play a larger role in VR-based than in traditional communication scenarios since immersive presentation (e.g., using stereoscopic displays) typically intensifies emotional experiences (e.g., Visch, Tan, & Molenaar, 2010). As a future featuring ubiquitous multimodal VR is gradually becoming a reality in a wide range of social and commercial settings (e.g., conversational agents and social VR applications), it is an urgent necessity to investigate the potential of embodied virtual agents for non-verbal persuasion as well as the interindividual variation in proneness to this persuasion. By examining these questions, one can provide new insight into the socio-emotional processes and individual

differences involved in persuasive human-computer interaction (HCI). Moreover, as human behavior and experience in VR may be largely congruent with behavior and experiences in physical settings (Bombari, Schmid, Canadas, & Bachmann, 2015), examining nonverbal persuasion in VR can provide new insight into affective interaction in general.

1.1 Current study

The current study addresses the aforementioned knowledge gap by investigating whether an embodied, virtual agent's facial expressions and touch affect compliance. Compliance is defined here as successful persuasion and measured using the economic game of ultimatum. In the game, one player (the proposer) is asked to make an offer to divide a sum of money between themselves and another player (the receiver). The receiver has the ultimate power to accept or reject the offer, but rejecting means that neither player receives anything. The ultimatum game offers a well-defined setting for measuring social psychological effects on compliance, as, contrary to the economically optimal strategy to accept every offer, people tend to reject offers that are unfair to them (e.g., Bolton & Zwick, 1995). Earlier neuroimaging research has demonstrated that the "irrational" decision to reject an offer is largely determined by emotional processes (Sanfey, Rilling, Aronson, Nystrom, & Cohen, 2003). Therefore, we assume that the proposer's nonverbal behaviors may influence the rejection decision because they influence the emotional processes underlying the decision. More specifically, our first hypothesis (H1) predicts that receiving a touch or perceiving a smile results in higher compliance than no touch or a non-affiliative facial expression, respectively.

The ultimate decision to accept or reject is itself a consequence of complex socio-cognitive evaluations that are believed to be very fast and sometimes outside the reach of conscious control (Osumi & Ohira, 2009). Measuring the brief delays in the cardiac cycle (i.e., cardiac deceleration/orienting response) may provide insight into such unconscious processes. For example, cardiac decelerations indicate an increased sensory intake (Bradley, 2009) and have been observed to occur in response to perceiving unfair offers in

the ultimatum game (Osumi & Ohira, 2009; Van der Veen & Sahibdin, 2011). Moreover, decelerations in cardiac activity are responsive to nonverbal emotional cues, such as touch, facial expressions (Harjunen, Spapé, Ahmed, Jacucci, & Ravaja, 2017), and pictures of threatening situations (Bradley, Lang, & Cuthbert, 1993). Therefore, cardiac deceleration may reflect both affective reaction related to the unfair offer as well as the influences of emotional nonverbal cues. This leads to our second hypothesis (H2): Unfair offers induce stronger cardiac deceleration than fair or generous offers, while a proposer's touch and smile should attenuate this unfairness-related deceleration.

As people differ in their responsiveness to emotional cues (Balconi, Falbo, & Conte, 2012) and willingness to take economic risks (Ferguson, Heckman, & Corr, 2011), we assume that some individuals are especially prone to machine persuasion as well. Furthermore, if machine persuasion is similar to human persuasion, we should assume that personality modulates the degree to which nonverbal cues affect compliance. Given that the literature does not currently sustain any clear predictions, the present study explores relevant individual differences and the degree to which these affect nonverbal communication in machine persuasion.

Among the relevant personality traits, differences in approach (seeking of reward) and withdrawal (avoiding negative experiences) tendencies are of particular importance when it comes to responding to emotional cues (Balconi, Falbo, & Conte, 2012) and making economic decisions (Ferguson et al., 2011). These two motivational tendencies are well captured by two neurobiological regulation systems: the behavioral activation and inhibition systems (Carver & White, 1994). Behavioral activation system sensitivity (BAS) is associated with enhanced self-reported positive valence and increased cardiac-orienting responses when perceiving an appetitive emotional stimulus (Balconi, Brambilla, & Falbo, 2009). Behavioral inhibition system sensitivity (BIS), in turn, has been linked to heightened responsivity to negative facial expressions (Knyazev, Bocharov, Slobodskaya, & Ryabichenko, 2008) and touch (Harjunen et al., 2017). With regard to economic decisions, high-BAS individuals have been shown to accept monetary offers more easily than low-BAS persons in the ultimatum game and to be more likely to

defect in the prisoner's dilemma game to maximize the economic gains (Scheres & Sanfey, 2006; Ferguson et al., 2011).

BIS and BAS may be good in reflecting general motivational tendencies but fall short in capturing more context-specific features of the decision-making task. Players in the ultimatum game need to balance between economic gains and fairness, which causes people's average rejection rate to vary according to their sensitivity to unfair treatment (Fetchenhauer & Huang, 2004). In fact, high ratings in this so-called justice sensitivity (JS) trait have been associated with higher rates of rejection and stronger activity in neural substrates that are responsive to error and pain when receiving an unfair offer (Fetchenhauer & Huang, 2004; Boksem & De Creme, 2009). One could assume, therefore, that high justice sensitivity makes nonverbal persuasion less effective because of the person's readiness and responsiveness to unequal deals.

As the analysis of the individual differences in nonverbal persuasion is more explorative, we make no precise predictions about how each trait relates to specific nonverbal cues, and we present two more general hypotheses based on the findings reviewed above. First (H3), we hypothesize that persons with high BAS will be more compliant and perceive touch and smile as being more persuasive than low-BAS individuals will. Secondly (H4), we assume that persons with high JS and BIS will show lower compliance to unfair offers and be less sensitive to the persuasiveness of touch and facial expressions than those scoring low in these traits.

The present study utilized an iterative version of the ultimatum game in which both the responder (i.e., the participant receives the offer) and proposer (i.e., the participant makes the offer) trials were repeated multiple times with eight virtual agents. Proposer trials were used to make the experiment feel less repetitive and more meaningful for the participants. However, because proposer behavior is more related to generosity than compliance (Spape et al., 2015), we limited our analyses to data obtained from responders.

2 Materials and Methods

2.1 Participants

Sixty-six undergraduates from the University of Helsinki and Aalto University were recruited to take part in the study. All of the participants were healthy adults with normal or corrected-to-normal eyesight, and none had a history of neurological or psychopathological disorders (or other chronic health issues). Before signing their informed consent, participants were informed of their rights to withdraw from the study at any moment and that the default compensation for their time would be €35 but they could earn an extra amount ranging from €1 to €35 depending on their decisions in the game. Nine participants were excluded from the analysis for accepting more than 95% of the offers, and one was excluded due to a technical issue. (A more precise description of the exclusion criteria can be found in Appendix A.1.) The final sample consisted of 32 females and 24 males, both having a similar age range (females: M = 24.28, SD = 5.22; males: M = 25.65, SD = 4.67). The study was conducted following the guidelines of the National Advisory Body on Research Ethics in Finland and approved by the Research Ethics Committee of Aalto University. The obtained research data are made available on Open Science Framework repository (Harjunen, Spape, Ahmed, Jacucci, & Ravaja, 2018).

2.2 Procedure and design

The participants were seated at a desk equipped with a glass table and motion-tracking sensors. Following the instructions, the participants were assisted with putting on a head-mounted display (HMD) and a tactile glove (Figure 1, panel A). Through the HMD, the participants could see the word "Respond" or "Propose" cuing the participant's role in the upcoming trial. A virtual reality was then presented, in which the participants could see their right hand resting on a table and moving based on their own hand. Moving the hand over the crosshair launched a random delay lasting 0-200 ms, after which a 1,700 ms animation of a facial emotional expression was displayed. In visual and visuo-tactile touch trials, the facial

expression was accompanied by a reaching gesture starting at 0-200 ms (randomized) after the expression's onset. In the visual and visuo-tactile touch conditions, the agent moved its right hand toward the participant's hand, which took 1,000 ms. Upon contact, the glove sent 500 ms of tactile feedback if a visuo-tactile condition was presented. However, no feedback was sent in case of visual touch or in the no-touch condition, and no reaching gesture was shown in the no-touch condition. The VR environment was then replaced by a black screen with a fixation crosshair shown in the middle, after which the beginning screen of the ultimatum game part started. In the role of receiver, participants first saw the agent's proposal presented as two numbers within a grey frame. The proposal was then replaced by a response cue indicating that the participant could accept the offer by pressing the left arrow key and reject it by pressing the right arrow key. The next trial was presented after a blank intertrial interval. Figure 1 (panel C) presents the complete structure of the response trials and the exact timing of each step.
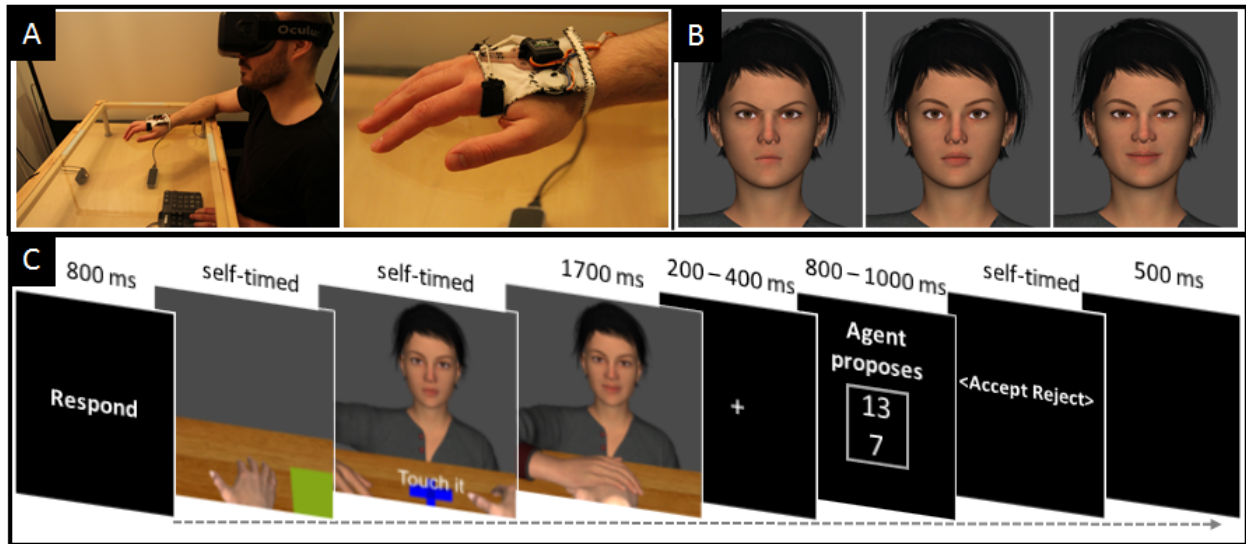

Figure 1. Panel A shows the physical settings, HMD, and haptic glove. In panel B, the facial expressions (angry, neutral, and happy, respectively) are illustrated. Panel C depicts the temporal flow of the responder trials, with the timing of each phase indexed above. The latency of the fixation cross and proposal feedback were randomized between trials.

Each participant went through 594 trials organized in nine blocks. The first block consisted of 18 orientation trials with extensive instructions and feedback, whereas the following eight blocks had 72

trials each and more concise feedback. Apart from the orientation, each block consisted of four series of 18 proposer trials and responder trials. Touch type (no touch, visual, visuo-tactile), facial expression (angry, neutral, happy), and, in case a responder trial was shown, offer type (very unfair: €2-€6 for the participant|€18-€14 for oneself, somewhat unfair: €7-€8|€12-€13, fair: €10|€10, generous: €11-€15|€5-€9) were randomly presented within each block. In each responder trial, participants received an offer from the agent that was selected by a simple selection algorithm. The algorithm was based on approach used by Boksem and De Cremer (2009), in which the probability of making fair offers was higher than that of making unfair ones. A detailed description of the algorithm can be found in Appendix B.1 (Fig. B.1).

After completing a block, participants could have a self-timed break. During the break, they received feedback on how much money they had earned so far. The average duration of the experiment was 150 minutes, including preparation.

2.3 Stimuli and apparatus

2.3.1 Emotional expressions. Agents' facial emotional expressions were created with Unity 3D 4.5.4 software (Unity Technologies, San Francisco, CA). The face contained action units that could be dynamically manipulated to create expressions of six basic emotions, according to Ekman and Friesen (1976). In the beginning, we created a set of 42 expression animations—six for each of the seven emotion categories (happiness, anger, fear, disgust, surprise, sadness, and neutral). The animations were then validated by a separate sample of 13 participants. Only the neutral, happy, and angry expressions were used in the present study, since the other expressions were considered less suitable for the current context. The pilot study revealed average recognition accuracies of 70% for anger, 98% for happiness, and 100% for neutral expression.

2.3.2 Tactile stimuli. The participants were instructed to place their right hand on top of a glass table while a Leap Motion (www.leapmotion.com) controller, placed 16 cm below the hand, tracked the

participant's movements and reflected them into VR (see Figure 1, panel A). Dynamic presentation of the participant's hand movements created a sense of agency over the participant's virtual body. The sensation of touch was enabled upon skin contact in VR using a tactile glove developed by Ahmed et al. (2016). The glove works by creating mechanical pressure over users' metacarpal bones. The pressure is applied by a servomotor stretching two elastic tapes over the volar of the hand. Recent studies on mediated multimodal communication have found that this sort of pressure feedback better approximates real human touch than more commonly used vibrotactile stimuli (Ahmed et al., 2016). The maximum intensity of the pressure was reached when the lever of the motor rotated 180° (see Figure 1, panel A, right hand side). Each touch stimulus lasted for 0.5 s and had the maximum level of intensity. Finally, a masking sound was played throughout the experiment to prevent biases due to auditory cues.

2.3.3 Virtual reality. Agents and the environment were presented via an Oculus Rift head-mounted display (Developer Kit 2, 960 x 1080 pixels per eye; 75 Hz refresh rate; 100° nominal field of view). The Rift enabled an immersive visual experience utilizing a combination of positional tracking and stereoscopic and parallax cues. The agents were manually morphed from male and female Genesis 2 characters from Daz Studio (Daz3D, Salt Lake City, UT). In order to increase the diversity in the virtual agents' appearance, four pairs of male and female agents were created, with each pair possessing features related to four ethnic backgrounds (Caucasian, African, East Asian, and South Asian; see Appendix C.1, fig. C.1). Objects like the virtual table and cues were created using Unity3D software (Unity Technologies, San Francisco, CA). The user's virtual hand was the default hand model of Leap Motion's Unity3D package. After defining all of the static properties, both the agents and objects were transferred to the Unity 3D software, which was used to model the agent's touch gestures and the surrounding environment. Custom-made software was then designed with Unity 3D to control the stimulus presentation, record decision behaviors, and send triggers to the ECG amplifier. The presentation software ran on an Intel-based desktop PC equipped with Windows 7 operating system. Ravaja et al. (2017) previously used the aforementioned VR setup.

2.4 Measures

2.4.1 Compliance. Compliance was operationalized as a binary decision to either accept or reject the agent's offer in the responder trials. The analysis was done on a trial-to-trial level.

2.4.2 Personality. The Justice Sensitivity Questionnaire by Schmitt, Gollwitzer, Maes, and Arbach (2005) was used to measure each participant's general tolerance to unfair treatment. The measure has been proofed as a valid and reliable measure of interindividual variability in reactions to unfair situations (Schmitt, Baumert, Gollwitzer, & Maes, 2010). The questionnaire has three subscales, of which we used only the JS_{Victim} subscale of 10 items, as it measures person's proneness to experience injustice toward oneself. Items were rated using a 5-point Likert scale (1 = *disagree strongly*, 5 = *agree strongly*). The Cronbach's alpha for the 10 item scale showed acceptable internal consistency (α = .76). Average of the 10 items was used as the score of JS_{Victim}. Individual differences in behavioral activation and inhibition systems were measured using the BIS/BAS Scale developed by Carver and White (1994). The scale consists of four subscales (24 items), but only the BAS-Reward Responsiveness Scale (4 items) and BIS scale (7 items) were used. BAS-Reward Responsiveness measures a person's sensitivity to rewarding experiences and has been found to better capture individual differences in approach motivation than the other two BAS subscales: BAS-Fun Seeking and BAS-Drive (Taubitz, Pedersen, & Larson, 2015). Participants gave their responses using a 4-point Likert scale (1 = *very false for me*, 4 = *very true for me*). The Cronbach's alpha for the BAS-Reward and BIS scales indicated acceptable internal consistency (α_{BAS} = .73 and α_{BIS} = .75). Averages of the items were used as the scores of BAS-Reward and BIS.

2.4.2 Cardiovascular responses and data cleaning. ECG was recorded using a QuickAmp (BrainProducts GmbH, Gilching, Germany) amplifier and disposable ECG electrodes (H93SG, size: 42 mm × 24 mm, Covidien/Kendall, Minneapolis, MN) placed at the upper sternum (manubrium) and the second-lowest left-hand rib. The obtained ECG signal was digitized at a 1,000 Hz sample rate and reprocessed using an R-peak detection algorithm running on MATLAB, which interpolated the signal to

interbeat intervals (IBI) and segmented them into 9-s epochs, with time locked to offer feedback onset. Each epoch contained 1,500 ms of baseline activity that was removed from the post-stimulus activity. Visual inspection of the baseline-corrected grand average (across conditions) IBI response suggested a cardiac deceleration occurring 1000-3000 ms after offer feedback, which is in accordance with earlier literature (Bradley, 2009). Trial-based cardiac deceleration was then calculated by averaging the baseline corrected IBI values from the post-offer stimulus interval of 1000-3000 ms.

As a result of movement artifacts, failure to detect R-peaks from the ECG signal, or unexpected issues in data recording (detached electrodes), a total of 1,303 trials with erroneous IBI values were obtained. Removing these artifactual trials resulted in a 4.52% decrease in the data. Additionally, given that each participant had to go through 596 game trials, they were encouraged to respond quickly. Trials with extremely long decision times (5,000 ms post-offer feedback) were taken as signs of distracted attention and were excluded from the analysis. The threshold of 5,000 ms was selected as a safe cutoff based on the distribution of RTs (excluding only 0.43% of the remaining data). The final data set consisted of 56 participants and 23,438 observations.

2.5 Analysis and design

First, we investigated whether the virtual agent's expression and touch promoted compliance in the participants (H1). Given the multilevel structure of the data (repeated measures clustered on participants), the generalized estimating equation (GEE, geepack in R; Halekoh, Højsgaard, & Yan, 2006) with the binary logistic link function was used to carry out the analyses. The GEE is used to analyze data that are clustered under more than one level (e.g., repeated measures within participants), making it a suitable method for repeated-measures designs (Liang & Zeger, 1986). In the GEE approach, one has to specify the working correlation matrix structure for the repeated measures. Here, the first-order autoregressive structure (ar1) was selected based on the lowest quasi-likelihood under independence model criterion (QIC) value.

The model included the main effects of offer type, expression, touch, agent gender (same vs. different from the participant's own), and ethnicity (Caucasian vs. African vs. East Asian vs. South Asian). A binary factor of time (first vs. last half of the experiment) was also included to control for habituation effects. According to H1, the effects of expression and touch should show up particularly with unfair offers. Thus, the two-way interactions of expression and offer type as well as touch and offer were tested. In addition, it was possible that the effect of touch depended on expression. Therefore, the two-way interaction of expression and touch as well as the three-way interaction of expression, touch, and offer were added. The contribution of each main and interaction effect on model fit was tested with the Wald χ^2 test with type III sum of squares. The effect sizes were reported as odds ratios (*OR*s).

A multilevel linear modeling (MLM) with restricted maximum likelihood estimation was used to test whether touch and expression influenced responders' post-offer cardiac decelerations (H2). The MLM was conducted using the lme4 package in R (Bates, Mächler, Bolker, & Walker, 2014). MLM assumes a linear relationship between categorical or continuous predictors and a continuous dependent variable that can be clustered and vary on two or more levels (Raudenbush & Bryk, 2002).

The MLM had cardiac deceleration as the outcome and gender, ethnicity, offer type, expression, and touch as factors. The same effects were tested as in the GEE model described earlier. Moreover, due to the commonly demonstrated habituation effect in cardiac deceleration (Bradley, Lang, & Cuthbert, 1993), a binary factor of time (the first half of the session vs. the last half of the session) was included. Preliminary inspection revealed individual differences in the temporal trends; thus, the factor of time was also set as a random slope, while the participant ID was assigned to a random intercept. The pseudo-R^2 was used to indicate the proportion of explained variance, and the omega-squared effect size measure was used to indicate the proportion of residual variation explained by individual predictors (Ω^2, Xu, 2003).

The final phase of the analyses was aimed at investigating whether the responder's JS, BAS, and BIS moderated the effects of touch and expression on compliance (H3b). The tests were carried out by

building three additional GEE models, in which the previously described situational factors were accompanied by trait covariates. The trait covariates were standardized to have a mean of 0 and a standard deviation of 1. To avoid overly complex model structures and multicollinearity between the covariates, we decided to use separate models for each trait covariate. In addition to the situational factors, each of the models included the main effect of trait (JS/BAS/BIS) as well as the two- and three-way interactions between touch, expression, offer, and trait.

3 Results

3.1 Effect of touch and facial expressions on receiver's decisions and physiology

The participants accepted 68.30% ($SD = 46.53\%$) of the offers, on average. The presentation of the agent's offer on the screen resulted in an average deceleration of 30.38 ms ($SD = 54.67$ ms) in cardiac cycle. As demonstrated in table 1, the probability of accepting offers as well as the offer-related cardiac deceleration varied as a function of the offer type.

Table 1. Means and standard deviations of the receiver's compliance and post-offer cardiac deceleration, presented as a function of offer

Offer type	P(accept)		Cardiac deceleration		
	M	*(SD)*	*M*	*(SD)*	*n*
Very Unfair	0.20	0.40	32.78	54.13	6,290
Somewhat Unfair	0.69	0.46	30.88	54.92	5,441
Fair	0.94	0.24	29.44	54.85	5,868
Generous	0.94	0.24	28.27	54.77	5,839

Note. Values of *n* represent the total amount of observations within each condition. The trials for each condition were originally balanced, but some minor variation was obtained because of data cleaning.

The GEE analysis showed a significant main effect of offer type, with low shares resulting in frequent rejection. As shown in table 2 (left-hand side), significant main effects of time, ethnicity, facial expressions, and touch as well as two-way interactions between offer type and touch and between offer

type and expression were found. Participants accepted fewer offers during the first half of the experiment (M = .68, SE = .02) compared to during the last half of the experiment (M = .68, SE = .02, p = .01, OR = 1.13, 95% CI [1.09, 1.15]). Tukey-adjusted pairwise comparisons of ethnicity revealed that the participants were more likely to accept offers presented by African (M = .70, SE = .02) versus Caucasian models (M = .68, SE = .02, p = .04, OR = 1.10, 95% CI [1.09, 1.11]).

Table 2. Wald χ^2 test results of GEE and MLM models predicting compliance and post-offer cardiac deceleration

Effects	P(accept)			Cardiac deceleration		
	Wald χ^2	df	p	Wald χ^2	df	p
Time	6.13	1	.013	0.14	1	.713
Agent Ethnicity	11.84	3	.008	4.16	3	.244
Agent Gender	0.36	1	.550	4.25	1	.039
Fairness	320.06	3	<.001	23.60	3	<.001
Expression	48.43	2	<.001	1.31	2	.519
Touch	3.43	2	.180	0.92	2	.632
Fairness x Expression	22.71	6	.001	5.24	6	.513
Fairness x Touch	18.07	6	.006	8.16	6	.227
Expression x Touch	8.34	4	.080	7.76	4	.101
Fairness x Expression x Touch	10.69	12	.555	7.76	12	.804

Note. On the left, one can see the Wald test statistics of the GEE model for compliance; on the right, one can see the equivalent statistics for the MLM on post-offer cardiac deceleration. In both cases, the χ^2 refers to Wald χ^2 test results calculated based on type III sum of squares.

H1 predicted that happy/neutral expressions and touch from the agent would result in higher compliance with unfair offers than the angry expression and no-touch conditions. Planned pairwise comparisons between the neutral and angry expression conditions and the happy and angry expression conditions revealed that happy and neutral expressions resulted in higher compliance than angry expression and that the effect was stronger in fair (p < .001, ORs ≤ 4.83) and generous (p < .001, ORs ≤ 4.04) offer conditions than in somewhat unfair (p < .001, ORs ≤ 2.06) or very unfair (p < .001, ORs ≤ 1.63) offers (see figure 2, panel A). Moreover, the hypothesized effect of touch was also found (see figure 2, panel B). Receiving a

visuo-tactile resulted in higher probability of accepting very unfair offers than when no touch was delivered ($p = .03$, $OR = 1.20$, 95% CI [1.16, 1.28]). No significant difference was found between the visual and no-touch conditions ($p = .29$). While the persuasiveness of visuo-tactile touch ($M = 70$, $SE = .02$) vs. no touch ($M = 68$, $SE = .01$) was also present in somewhat unfair offers, it failed to reach significance ($p = .06$, $OR = 1.13$, 95% CI [1.13, 1.16]). Moreover, no significant two-way interaction between touch and expression ($p = .08$) or three-way interaction between touch, expression, and offer type was found ($p = .56$).

Figure 2. Interaction effects of expression and offer (panel A) and touch and offer (panel B) on compliance. The least square means of log-odds were back-transformed to probability, and the error bars indicate the standard errors of the planned pairwise comparisons between angry vs. neutral/happy (panel A) and no touch vs. visual/visuo-tactile (panel B) at each level of offer.

Next, we investigated whether unfairness of the offer increased post-offer cardiac deceleration and whether this fairness-related deceleration was modulated by the agent's touch and facial expressions (H2). The last two columns of table 1 describe the average cardiac deceleration as a function of offer. As can be seen, unfair offers resulted in longer interbeat intervals than fair and generous offers. Table 2 (right hand side) shows the results of the MLM analysis. First, no fixed effect of time was found ($p = .71$), but the random effect was significant, $\chi^2(2) = 88.13$, $p < .001$, referring to significant individual differences in the temporal trends of cardiac deceleration. In addition, the agent's gender was found to affect the deceleration ($p = .04$, $\Omega^2 = .0001$), suggesting a smaller deceleration in response offers from opposite-sex

agents (M = 29.81 ms, SE = 1.79) as compared to same-sex agents (M = 31.24 ms, SE = 1.79). Moreover, as predicted by H2, there was a significant negative relation between offer size and cardiac deceleration, p < .001, Ω^2 = .0009. Finally, and contrary to H2, neither the main effects of expression or touch nor the interactions between offer, touch, and expression were significant (ps > .10). As indicated by the pseudo-R^2 of .067, the full model was able to explain only 6.7% of the variation in cardiac deceleration. Furthermore, the intraclass correlation (ICC = .06) calculated based on the MLM indicated that 6% of the total variance in cardiac deceleration was accounted for by differences between subjects, and 94% of the variance was accounted for by within-subject effects.

3.2 Individual differences in vulnerability to virtual agent's persuasion

To uncover the variability in proneness to nonverbal persuasion, we investigated whether individual differences in BAS, BIS, and JS moderate the effects of touch and facial expressions on compliance (H3, H4). Table 3 presents the means, standard deviations, and correlations of averaged compliance with unfair offers, averaged cardiac deceleration in unfair offers, and personality traits. As can be seen, BAS, BIS, and JS are all positively correlated with each other (ps < .01). In addition, a significant positive relation between compliance and BAS was obtained (p = .03). However, no associations were found between the cardiac deceleration and averaged compliance (p = .39) or the trait variables and cardiac deceleration (ps > .18).

Table 3. Means, standard deviations (SD), and Pearson correlations of receivers' average compliance with unfair offers, post-offer cardiac deceleration induced by an unfair offer, and personality traits

Variable	M	(SD)	Cardiac d.	JS	BAS	BIS
P(accept unfair)	0.68	0.13	−.12	−.16	.29*	.01
BIS	2.83	0.49	−.04	.41**	.35*	
BAS	3.28	0.50	.14	.29*		
JS	3.32	0.58	.18			
Cardiac d. (unfair)	32.06	13.81				

Note. N = 56 for all correlations. Cardiac deceleration, compliance, and generosity were averaged over repeated trials to obtain subject-level mean scores. * p < .05, ** p < .01.

Table 4 shows the results of the GEE model. Along the predictions of H3, people with high BAS were more likely to accept any kind of offer than people with low BAS ($p = .02$; see M1 of table 4). In addition, a two-way interaction between touch and BAS was obtained ($p = .02$), as was a three-way interaction among BAS, offer type, and touch ($p = .03$).

Table 4. GEE analysis results regarding the effect of the receiver's behavioral approach tendency (BAS), behavioral inhibition tendency (BIS), and justice sensitivity (JS) on the persuasiveness of nonverbal cues

Effects	M1 JS			Effects	M1 BAS			Effects	M1 BIS		
	χ^2	df	p		χ^2	df	p		χ^2	df	p
Time	6.64	1	.010	Time	6.67	1	.010	Time	6.21	1	.013
Agent Ethnicity	12.40	3	.006	Agent Ethnicity	12.39	3	.006	Agent Ethnicity	11.30	3	.010
Agent Gender	0.40	1	.525	Agent Gender	0.34	1	.561	Agent Gender	0.25	1	.617
Fairness	351.48	3	<.001	Fairness	357.35	3	<.001	Fairness	331.03	3	<.001
Expression	43.40	2	<.001	Expression	42.92	2	<.001	Expression	55.04	2	<.001
Touch	1.14	2	.566	Touch	4.57	2	.102	Touch	2.57	2	.277
JS	0.01	1	.911	BAS	5.32	1	.021	BIS	0.60	1	.437
Fairness x Expression	26.17	6	<.001	Fairness x Expression	20.24	6	.003	Fairness x Expression	26.34	6	<.001
Fairness x Touch	15.49	6	.017	Fairness x Touch	19.75	6	.003	Fairness x Touch	22.20	6	.001
Fairness x JS	18.56	3	<.001	Fairness x BAS	5.85	3	.119	Fairness x BIS	10.82	3	.013
Expression x Touch	6.74	4	.150	Expression x Touch	9.12	4	.058	Expression x Touch	7.92	4	.095
Expression x JS	0.27	2	.873	Expression x BAS	4.55	2	.103	Expression x BIS	0.30	2	.860
Touch x JS	0.88	2	.645	Touch x BAS	7.42	2	.024	Touch x BIS	2.62	2	.270
Fairness x Expression x Touch	9.49	12	.661	Fairness x Expression x Touch	13.07	12	.364	Fairness x Expression x Touch	15.75	12	.203
Fairness x Expression x JS	6.52	6	.368	Fairness x Expression x BAS	8.72	6	.190	Fairness x Expression x BIS	23.23	6	.001
Fairness x Touch x JS	32.27	6	<.001	Fairness x Touch x BAS	14.24	6	.027	Fairness x Touch x BIS	6.39	6	.381
Expression x Touch x JS	6.16	4	.187	Expression x Touch x BAS	0.30	4	.990	Expression x Touch x BIS	6.88	4	.142
Fairness x Expression x Touch x JS	19.53	12	.076	Fairness x Expression x Touch x BAS	13.43	12	.339	Fairness x Expression x Touch x BIS	17.18	12	.143

Note. M1 includes Wald test statistics of the main and interaction effects of the receiver's BAS, M2 includes the main and interaction effects of the receiver's BIS, and M3 includes the main and interaction effects of JS. The χ^2 refers to Wald χ^2 test results calculated based on type III sum of squares.

Inspection of the effect revealed that those with weak BAS (−2 *SD*) were almost two times (*OR* visuo-tactile vs. no touch = 1.74, 95% CI [1.68, 1.81], *OR* visual vs. no touch = 1.54, 95% CI [1.50, 1.58]) more likely to accept a very unfair offer if being touched (visually or tactilely) than if not being touched. Such effect was not present in high-BAS individuals or when the offer was somewhat unfair, fair, or generous (see figure 3, panel A). Contrary to the assumption regarding facial expressions and BAS, no evidence was found for the interactions between BAS and expression on compliance (*p*s > .10).

Moreover, BIS was found to moderate the effect of expressions (see M2 in table 4). While the main effect of BIS was not significant (*p* = .44), an interaction between offer type and BIS was found (*p* = .01). In line with H4, this effect was further affected by the agent's expression (*p* = .001). As can be seen from Figure 3 (panel B), people with high BIS (+2 *SD*) showed lower compliance with very unfair offers coming from angry agents than those coming from neutral or happy agents (*OR* neutral vs. angry = 2.93, 95% CI [2.76, 3.11], *OR* happy vs. angry = 2.42, 95% CI [2.29, 2.54]). In addition, low-BIS individuals (−1 *SD*) showed lower compliance with fair and generous offers made by angry agents than those made by happy and neutral agents (*OR*s > 3.44). Contrary to BAS, however, BIS did not moderate the effect of touch (*p*s > .14).

Replacing BIS with JS (M3, see table 4) revealed significant interaction effects between the offer and JS (*p* < .001) as well as among offer, JS, and touch (*p* < .001). Inspection of the three-way interaction revealed that, in line with H4, people with low JS (-2 *SD*) were about 1.5 times (*OR* visuo-tactile vs. no touch = 1.50, 95% CI [1.48, 1.51], *OR* visual vs. no touch = 1.66, 95% CI [1.64, 1.67]) more likely to accept very unfair offers when being visually or tactilely touched by the agent than if no touch was delivered. Such an effect was not obtained in high-JS persons or in other offer types (see figure 3, panel C). However, partially contrary to H4, no interaction between expression and JS was found (*p* = .87). Similarly, there were no significant three-way interactions among offer type, expression, and JS or among expression, touch, and JS (*p*s > .08).
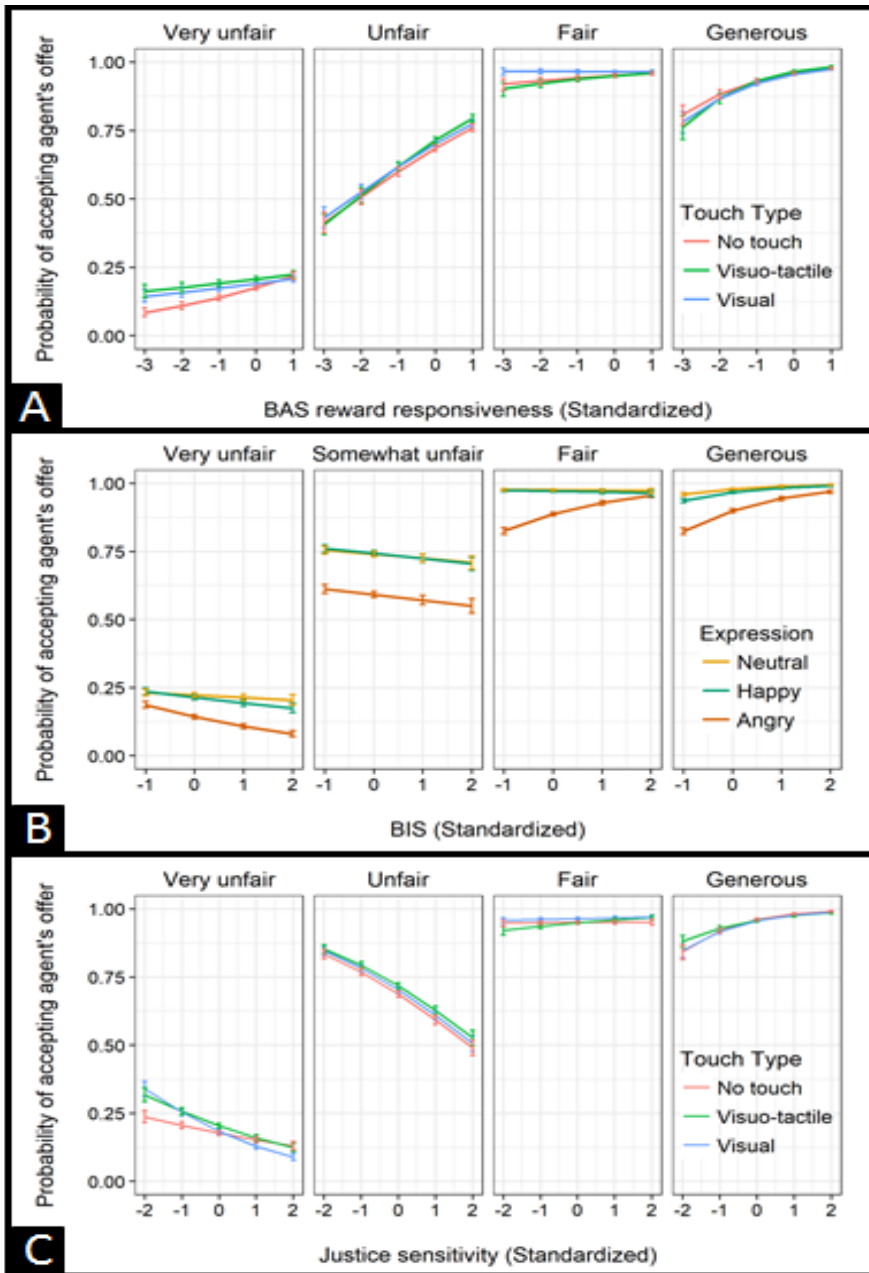
Figure 3. Moderating effects of receiver's justice sensitivity, BAS, and BIS on the persuasiveness of the agent's touch and facial expressions. The outcome was back-transformed to probability, and the error bars indicate the standard errors of the least square means.

4 Discussion

The present study examined the persuasive influences of affective nonverbal communication of embodied virtual agents and how individual differences in motivational traits and justice sensitivity modulate proneness to agents' persuasive impact. To uncover the socio-cognitive mechanisms that underlie the persuasive influence, we measured the receiver's post-offer cardiac deceleration and found it to be responsive to offer fairness but not to nonverbal cues. Further investigation of the impact of motivational traits and justice sensitivity revealed a group of individuals who were particularly prone to nonverbal persuasion. In the following paragraphs, we will go through some of the unexpected findings and elaborate upon the complex state- and trait-level dynamics uncovered by the study.

With regard to the agents' facial cues, the participants accepted the proposer's offers more readily if accompanied by a happy or neutral expression than when an angry expression was shown. This was in line with previous findings by Mussel et al. (2013). However, the anger-related rejections were visible not only in unfair proposals but also in equal and generous offers. Rejections in ultimatum games have been shown to reflect the responder's motivation to penalize the proposer for making an unfair offer (Bolton & Zwick, 1995). Therefore, the effect could be interpreted in terms of retaliation rather than compliance. That is, people punished proposers who expressed anger and not just complied with those who smiled.

Moreover, clear evidence of the compliance-promoting influence of touch was found. Although small, the effect was in line with the Midas touch effect previously demonstrated in a human–human interaction context (Gallace & Spence, 2010). Of the controlled situational factors, gender did not predict compliance but time (first half vs. last half) and ethnicity did. Acceptance rates were higher in the beginning than in the end, which suggests that people habituated to the offer feedback over time. Additionally, participants accepted more offers from African than Caucasian agents, which may well be related to demand characteristics, such as a person's deliberate attempt to be seen as an unprejudiced individual (Dovidio, Kawakami, Johnson, Johnson, & Howard, 1997). Despite the significant effects of ethnicity and time, it is

important to note that the effects of touch and expressions remained significant after controlling for the other factors.

Previous ECG studies utilizing the ultimatum game suggest that people exhibited stronger cardiac deceleration in response to unfair vs. fair/generous offers (e.g., Osumi & Ohira, 2009). Our observations replicated this finding. However, neither touch nor expression moderated the fairness-related cardiac response. The agent's gender had a small effect on the post-offer deceleration but no other effects were found. While it is possible that nonverbal cues do not modulate unconscious offer perception, the substantial amount of unexplained variation in the deceleration of interbeat intervals and the non-significant correlation between deceleration and compliance imply that cardiac deceleration does not offer an accurate picture of the unconscious offer evaluation. Indeed, using indexes of brain activity, such as feedback-related negativity (FRN) obtained from EEG, researchers have demonstrated that a smile presented before an unfair offer modulates the neural processing of unfair proposals (Mussel, Hewig, Allen, Coles, & Miltner, 2014).

Besides revealing the underlying neural processes, we aimed to increase understanding of individual differences in proneness to nonverbal persuasion of embodied virtual agents. Previous studies have shown that approach and withdrawal tendencies affect a person's responses to nonverbal cues (e.g., Balconi et al., 2009) and economic offers (e.g., Fetchenhauer & Huang, 2004). We thus expected that high-BAS individuals would show high compliance and be easily persuaded, especially in the context of positive nonverbal cues. Although a positive relationship between behavioral activation system sensitivity (BAS) and compliance was obtained, the persuasive effect of touch was found in individuals with low rather than high BAS, and the moderating effect of BAS on expressions was completely absent. The findings suggest that high reward responsiveness does not make nonverbal cues more persuasive but low reward responsiveness does, especially when it comes to touch. This pattern was strikingly similar to that found in justice sensitivity, as it was also found to moderate the Midas touch effect but not the effect of touch. We will return to this similarity and its implications later on.

Examining the moderating effect of behavioral inhibition system sensitivity (BIS), instead, revealed a completely different pattern. Namely, high-BIS individuals were more likely to reject very unfair offers when sent by an angry agent, but BIS had no role in the Midas touch effect. Additionally, we found that low- rather than high-BIS persons were more likely to reject fair and generous offers if preceded by an angry face. According to previous research, high-BIS people perceive negative facial expressions as being more negative (Knyazev et al., 2008) and touch as being more threatening than low-BIS individuals do (Harjunen et al., 2017). Therefore, we hypothesized that high BIS would both attenuate the Midas touch effect and increase rejection rates in response to angry expressions. Only the latter hypothesis received support. The findings seem to suggest that BIS regulates individuals' motivation to punish wrongdoers (angry and unjust agents) and that the direction of the trait–situation relation depends on the anticipated consequences. For instance, one could speculate that high-BIS individuals, as compared to low-BIS ones, felt a stronger urge to punish the unfair agents who expressed anger but did not punish the angry agents in fair and generous offers because they anticipated negative consequences (like less generous offers in subsequent trials) due to retaliation.

The findings also suggest a dissociation between the persuasiveness of facial expressions and touch, as BIS moderated the effect of expressions but not touch. Earlier research presented touch as an ambiguous social signal that is especially sensitive to cultural norms and situational cues (Remland, Jones, & Brinkman, 1995; Gazzola et al., 2012). The social meanings of facial expressions of anger and joy are arguably less ambiguous, as they are recognized at better than chance level in all investigated human cultures (Elfenbein & Ambady, 2002). High-BIS individuals are especially vigilant to high-arousal negative stimuli, like pictures of spiders or angry faces (Balconi et al., 2009). We assume that this sensitivity to clearly negative events explains why high-BIS persons were selectively sensitive to angry vs. happy expressions but not to the more ambiguous touch vs. no-touch condition.

People who are highly sensitive to unfair treatment tend to accept fewer low offers in the ultimatum game (Fetchenhauer & Huang, 2004). Therefore, we hypothesized that people with high JS would be better at

detecting unfairness and thus less easily persuaded by the nonverbal cues. This was exactly what we found. While high-JS persons showed no Midas touch effect, those with low JS accepted very unfair offers more readily if being touched.

As noted earlier, JS and BAS had a very similar influence on nonverbal persuasion. Although unclear, we suggest that this similarity may be due to the dynamics of the ultimatum game, which works by evoking a conflict between short-term economic prospects and avoidance of unfair treatment (Sanfey, 2007). These potentials for economic gains and avoidance of unfairness are well captured by reward responsiveness and justice sensitivity. Therefore, the economic initiatives may be particularly salient to those who score high in the traits. Indeed, touch had the strongest persuasive influence in those with low BAS and low JS. One could thus conclude that the Midas touch effect is most pronounced in those who are neither keen on the proposal nor worried about losing their dignity if making an unequal deal.

4.1 Limitations and future research

Substantial progress has been made in the development of embodied conversational agents for health care and customer service and social VR applications in recent years (Fagan 2018; Provoost et al., 2017). The current study is particularly informative to this development and to the field of human-computer interaction in general as it clearly demonstrates the persuasive impact of multimodal affective cues of embodied virtual agents and reveals the substantial interindividual variation in the proneness to nonverbal machine-persuasion. At the same time, important ethical questions regarding machine-persuasion have raised as the study shows that there are individuals particularly vulnerable to the persuasiveness of artificial social cues such as virtual touch.

The current study does not reveal, however, to what extent the obtained findings are applicable- to natural human–human interaction. Sanfey et al. (2003) previously showed that the insular reaction to unfair offers was attenuated if sent by a non-depicted computer agent rather than by a human. Thus, we may expect a smaller degree of persuasion from an artificial agent that is known to lack a theory of mind. To what

extent this is the case, however, would require a systematic comparison of human–human and human–computer decision-making. This comparison should utilize immersive VR and multimodal presentation that allows strong sense of interpersonal proximity and physical contact.

Furthermore, the current study does not offer a precise picture of the neural processes underlying persuasion and compliance. Neuroimaging and electrophysiological studies have shown that receiving an unfair offer in the ultimatum game results in enhanced activity in the anterior cingulate cortex (ACC, see Boksem & De Cremer, 2009), anterior insula (AI), and dorsolateral prefrontal cortex (DLPFC) (Sanfey et al., 2003). These regions are typically responsive to unpredicted events and conflict, physical pain and social rejection, and emotion regulation, which implies that unfair treatment triggers a group of negatively valenced emotional processes that motivate punishment of wrongdoers and fosters mutual reciprocity and justice (Sanfey, 2007). While part of this negative reaction is also reflected in enhanced cardiac deceleration (Van der Veen & Sahibdin, 2011), it may give only a limited account of the underlying socio-cognitive process. Therefore, in the future, a broader set of physiological measures is required to understand how the persuasiveness of nonverbal behaviors appears on a physiological level.

4.1 Conclusion

To conclude, the current study reveals that facial cues and touch by embodied virtual agents invoke compliance in humans and that differences in motivational tendencies and fairness perception make some individuals particularly prone to this persuasive influence. The findings are important for developing viable immersive communication platforms that allow embodied persuasive interaction between humans and algorithm guided virtual agents. The contributions are not limited to HCI, however, but extend to marketing, behavioral economics, personality research, and social psychology as they bring new insight into the dynamics between economic decision-making, personality and nonverbal communication. For commercial development, the work demonstrates the importance of multimodal affective cues and how these cues can enrich interaction in VR.

Of course, touch and facial expressions are not the only forms of nonverbal communication. With advances in VR technology and robotics, previously studied social cues, such as posture, gaze, gestures, distance, prosodic features and verbal content, should be revisited for examining their persuasive potential in embodied forms of human-computer interaction. Further research is also needed to understand similarities and differences between human-human and human-computer pairs in terms of persuasion. Psychophysiological investigations may be particularly informative in this regard.

In the future, the role of embodied virtual agents in persuasive communication will become even more important, as people are increasingly interacting with social robots and algorithmic agents (Fortunati, Esposito, & Lugano, 2015; Prendinger & Ishizuka, 2013). Enabling emotional reactivity, realistic appearance, and artificial intelligence in virtual agents leads to greater perceived agency (see Fox et al., 2015), which in turn makes them more efficacious in customer service and advertisement. At that point, general social tendencies of humans as well as individual differences in proneness to nonverbal persuasion can be exploited, which makes the current investigation particularly relevant for the required scientific inquiry and ethical discussion.

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