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Authors

Fujiwara, Ken
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Gratch, Jonathan
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Synchrony facilitates altruistic decision making for non-human avatars

Ken Fujiwara [a], Rens Hoegen [b], Jonathan Gratch [b], Norah E. Dunbar [c,*]

[a] Department of Psychology, National Chung Cheng University, Taiwan
[b] Institute for Creative Technologies, University of Southern California, Los Angeles, CA, USA
[c] Department of Communication, University of California, Santa Barbara, CA, USA

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ABSTRACT

Synchrony is a natural part of human interaction and is often associated with a variety of prosocial outcomes including affinity and rapport. The purpose of this research was to examine whether human negotiators would synchronize their movements when working with non-human avatars and if so, whether that would affect their perceptions of their negotiations. Results suggest that participants synchronized their movements with the movements of non-human negotiation partners, that greater synchrony was observed when participants engaged in an integrative negotiation compared to a distributive negotiation, and participants that engaged in synchrony reported greater affiliation with their non-human partner. Synchrony also lead to giving more to the non-human agent in an integrative negotiation whereas it had no significant impact on the outcomes in a distributive negotiation. Implications for human-machine interaction are discussed.

In their seminal 1983 book on human-computer interaction (now known as HCI), Card, Moran, and Newell argue that humans do not operate computers, they communicate *with* them to accomplish tasks. As a discipline, HCI has emerged to bring together ideas from diverse fields such as psychology, engineering, computer science, design, sociology, and communication. Advances in automation now allow humans to have realistic interactions with virtual human interviewers and have interactive conversations that resemble human-human interactions (Lucas et al., 2017). The degree to which the human and non-human agent behaviors are synchronized with one another goes a long way toward building rapport and improving outcomes. In this paper, we examine how humans synchronize their movements with nonhuman interactive agents and the outcomes that result from those interactions.

1. What is synchrony and rapport?

Interpersonal synchrony is a pervasive and fundamental activity which defines us as humans and is learned in infancy. As a form of adaptation, it is the basis of social and biological development, it enables relationship development, facilitates social influence, marks personality and cultural differences, and is critical to establishing and maintaining social organization (Burgoon, Dunbar, & White, 2014). Synchrony refers to "similarity in rhythmic qualities and enmeshing or coordination of the behavioral patterns of both parties'' in an interaction (Burgoon, Stern, & Dillman, 1995, p. 128). It is often associated with a variety of pro-social outcomes including increased affiliation (Hove & Risen, 2009) and rapport, which is a feeling of connection, mutual attentiveness and positivity (Tickle-Degnen & Rosenthal, 1990). Specifically, synchrony has been shown to improve collaboration and problem-solving in groups (e.g. Miles, Lumsden, Flannigan, Allsop, & Marie, 2017) but sometimes can increase conflict, depending on the task at hand (Wood, Caldwell-Harris, & Stopa, 2018).

Bernieri and Rosenthal (1991) proposed that synchrony is composed of three components: simultaneous movement, rhythm, and the smooth meshing of interaction. Interaction rhythms are the sequences of identical behavior between interaction partners that occur over time. Simultaneous behaviors are defined as behaviors that are identical between interaction partners at the same point in time. Finally, behavioral meshing is when interaction partners behave in a way that is complementary and forms a meaningful whole. In behavioral meshing, interactants use functionally equivalent behaviors that could be different forms, which together form a seamless whole such as one partner nodding while another is gesticulating with a similar rhythm (Fujiwara et al., 2021). These behaviors might objectively be perceivable to a third-party observer but might not always result in perceptions of rapport or solidarity for the interactants themselves (Dunbar et al., 2020).

To what extent is synchrony strategic? Rennung and Göritz (2016)

* Corresponding author.
E-mail addresses: psykf@ccu.edu.tw (K. Fujiwara), rhoegen@ict.usc.edu (R. Hoegen), gratch@ict.usc.edu (J. Gratch), ndunbar@ucsb.edu (N.E. Dunbar).

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argue that interpersonal synchrony can occur both intentionally, as well as incidentally, comparing it to what Knoblich, Butterfill, and Sebanz (2011) call *planned coordination* (strategic and intentional) and *emergent coordination* (a result of simple "perception-action coupling"). Two concert-goers may entrain to the same beat of the band they are watching without having the goal of performing synchronous movements. Communication accommodation theory (CAT; Giles, 2016) explains that people seek to converge their style of communication to their speaking partner when they seek affiliation, attraction, or some form of social approval from them. We subjectively size up where we "stand" communicatively and adapt our communication appropriately and we do not resonate with nonaccommodating others (Burgoon, Dunbar, & Giles, 2017). It is both a natural, instinctive process as well as a strategic, communicative one.

Dunbar et al. (2020) goes further to posit, in their strategic synchrony hypothesis, that sometimes, message senders utilize the strategy of synchronizing their behaviors to their message receivers in order to create rapport and improve the chances that their messages will be believed. Rennung and Göritz (2016) argue that shared intentionality of synchrony creates greater prosociality because the imperative of representing and integrating another person's mental state to establish synchrony, as well as the existence of a common fate, facilitates interdependent self-construal. The improved sense of rapport from increased synchrony results from the lines between one's self and the interaction partner being blurred, thus improving cooperation and affiliation.

2. Synchrony with non-human avatars

If synchrony and rapport in human interactions benefits human decision-making, might this phenomenon benefit interactions with machines? Researchers in human-computer interaction and robotics have explored the role of synchrony and rapport with non-human partners. Much of this research has focused on machines that adapt their behavior to their human partner (i.e., system-to-user alignment), and findings suggest this can have important benefits. Such coordination can benefit subjective feelings. For example, robots that mimicked their partner's body orientation increased feelings of similarity and closeness (Choi, Kornfield, Takayama, & Mutlu, 2017). But further, such coordination has beneficial social outcomes. For example, Bailenson and Yee (2005) found that a digital character was more persuasive if it mimicked a participant's head movements, and Gratch and colleagues found that people spoke more fluently and disclosed more intimate information when a digital listener nodded and smiled at the appropriate time (Gratch & Lucas, 2021; Gratch, Wang, Gerten, & Fast, 2007).

Research has also shown that people spontaneously synchronize their speech and movements to non-human partners (i.e., user-to-system alignment), just as they do with human partners, though the function and social consequences of such synchrony is less clear. People spontaneously entrain their speech patterns to their machine partners. In terms of word choice, they begin to adopt a robot's vocabulary when engaged in a joint task (Iio et al., 2015), adjust the wordiness of their responses (von der Pütten, Hoffmann, Klatt, & Krämer, 2011) or the formality of their speech (Kühne, Rosenthal-von der Pütten, & Krämer, 2013). In terms of prosody, speakers align their speaking rate (Bell, Gustafson, & Heldner, 2003), as well as pitch and pause structure (Oviatt, Darves, & Coulston, 2004). People also synchronize their nonverbal movements with non-human actors, including aligning the rhythm of their gestures (Ansermin, Mostafaoui, Sargentini, & Gaussier, 2017) and mimicking facial expressions (Hofree, Ruvolo, Bartlett, & Winkielman, 2014).

It is unclear why people synchronize their behavior to machines as these behaviors typically do not benefit their machine partners. In the above-mentioned studies, the machines were simply following deterministic scripts and could not benefit from such adaptation, though this was not necessarily clear to participants. This may reflect the common "media equation" effect, i.e., that people unconsciously treat computers as social actors (Reeves & Nass, 1996); though some have argued this synchrony reflects strategic attempts to influence the interaction. For example, Branigan and colleagues argue that lexical and prosodic alignment reflects conscious attempts by speakers to improve the accuracy of speech recognition (Branigan, Pickering, Pearson, & McLean, 2010). As evidence of this, they found alignment was strongest when the machine was described as having less dialog competency. As an alternative, Bergmann and colleagues claimed that "speakers might align to express their affiliation with an interlocutor and to enhance their interpersonal relationship" but argued more research is required to unpack these mechanisms (Bergmann, Branigan, & Kopp, 2015).

3. Hypotheses

In the present study, we examined Bergmann and colleagues claim that synchrony with a machine (i.e., user-to-system alignment) reflects strategic attempts to establish a prosocial relationship with the machine partner. We examine this question in the context of a negotiation between participants and an interactive digital character. Negotiations form an interesting domain to study rapport and synchrony. Negotiations are an important and well-studied domain of social decision-making and, unlike many of the aforementioned studies, they involve elements of both cooperation and coopetition. Prior research on negotiation emphasizes the importance of establishing rapport in establishing cooperation and obtaining mutually-beneficial outcomes (Drolet & Morris, 2000). However, this research also emphasizes that synchrony can break down when the competitive aspects of negotiation are emphasized (Carnevale, Pruitt, & Seilheimer, 1981; Lanzetta & Englis, 1989). Competition-salience can be manipulated in various ways but one common approach via the goals each party brings to a negotiation. Following findings on human-to-human synchrony in negotiations, we hypothesize that synchrony with non-human negotiation partners will be greater when the potential for cooperation is salient and that participants use synchrony strategically to achieve social goals. In so-called "distributive" (or zero-sum) negotiations, participants are assigned objectives that are in direct conflict. For example, if two people want to split a pie, a bigger slice for one side leads to a smaller slice for the other, and thus, competition is rewarded. In contrast, in so-called "integrative" (or win-win) negotiations, participants are assigned complementary goals such that cooperation is rewarded. For example, if one person only wants the crust, and the other only wants the filling, both parties can get what they want (if they cooperate enough to discover this "integrative potential").

We form three hypotheses about the role of synchrony in human-agent negotiations:

H1. Participants will synchronize their movements with the movements of their non-human negotiation partner.

H2. Greater synchrony will occur when participants engage in an integrative negotiation (i.e., win-win) compared to distributive negotiations (i.e., win-lose).

H3. Participants that engage in synchrony will report greater affiliation with their non-human partner.

Prior research suggests that affiliation towards one's negotiation partner will influence concession-making, so in addition to these hypotheses, we also examine how synchrony impacts the outcomes participants obtain. People are not purely selfish in negotiations, but try to accommodate the other party's goals to some extent. For example, in the Dictator Game, one person is given an endowment of money that they could share or keep for themselves. On average, people give away about 40% of this endowment, motivated by social considerations like empathy or guilt (Fehr & Schmidt, 1999). The extent of this "other regard" is shaped by the relationship to the other party. For example, people make greater concessions to ingroup members than outgroup members (Balliet, Wu, & De Dreu, 2014) or to people they feel closer to

(Bohnet & Frey, 1999). Perceived competition also shapes concession-making. For example, simply describing the other side as a "partner" produces more sharing than describing the other side as an "opponent" (Burnham, McCabe, & Smith, 2000). Research on human-machine interaction has shown that these effects also hold, but to a lesser extent, in interactions with nonhuman partners. For example, people make more generous offers to AI partners that appear to be of the same race compared to AI partners that appear to be of a different race, yet overall, they are less generous to AI compared with human partners (de Melo, Carnevale, & Gratch, 2014). Similarly, people are more generous when an AI partner shows emotional expressions that signal cooperation, compared with displays that signal competition, yet the impact of these emotional displays is much stronger when people believe their partner is human (de Melo, Gratch, & Carnevale, 2015). Based on these findings we ask the following research question:

RQ1: How does participants' willingness to engage in synchrony impact their negotiated outcome?

4. Measuring synchrony with an avatar

Unless researchers employ painstaking manual coding, two common steps are required to assess synchrony: generating time series data and performing time series analysis. The same is true even for human-avatar communication. As for the former process, video-based tracking techniques have a great advantage because they avoid meticulous manual coding (Fujiwara et al., 2021). To date, two major options are recognized, the first of which is the so-called pixel or frame differentiation technique (Paxton & Dale, 2013; Ramseyer, 2020; Ramseyer & Tschacher, 2011). In general, the technique automatically calculates the change in grayscale pixels between consecutive video frames within a region of interest (ROI), which are encoded as movements if a camcorder were fixed and neither background nor lightning condition changed. The other option is one used by the OpenPose software (Cao, Simon, Wei, & Sheikh, 2017) that automatically detects the 2-D coordinates of the face and joints of a human body, such as nose, neck, shoulders, hands, and legs. This technique, which is based on a method of computer vision and deep learning, is advantageous because it is insensitive to background noise and lighting conditions. Besides, OpenPose (Cao et al., 2017) is applicable to avatars having a human-like appearance (see Fig. 1).

To compute synchrony, a diverse type of time-series analysis has been employed. For instance, cross-correlation, a simple extension of Pearson's correlation to time-series data, is broadly used (e.g., Schoenherr et al., 2019). Cross-recurrence quantification analysis is a nonlinear method for extracting co-visitation patterns between two systems, which focuses on synchronous patterns occurring in varying lags throughout conversation (Coco & Dale, 2014). Dynamic time warping (Berndt & Clifford, 1994) is also a non-linear method. It calculates a distance between two time series using the "warping" sequences in the time dimension, thus the distance score is considered as inverted to synchrony. They capture the convergence of timing in two speakers' movements. To investigate the rhythmic feature, another property of synchrony, spectrum analysis is another promising option. Spectrum analysis is an analysis technique for time-series signals in the frequency domain, which deconstructs complex time-series into rhythmic components, thus cross-spectrum analysis enables the researcher to assess synchrony from the perspective of rhythm (Fujiwara, Kimura, & Daibo, 2020). These kinds of time-series analysis offer the information regarding the convergence of timing or rhythm between two time-series, not the similarity of "behavior" that is categorized and counted/rated via manual coding.

In this study, we performed the dynamic time warping for each dyadic time series since cross-correlation and cross-recurrence quantification analysis have several parameters to be determined such that it was not easy to find the optimal parameters if there is no clear assumption regarding the time-series signal. Spectrum analysis was also not promising since the avatars moved only when they moved items on the negotiation table, which was not ideal to extract rhythmic features of their continuous movement. Therefore, the distance score calculated by dynamic time warping was the main variable (as an inverse) indicating the degree of synchrony.

To test the validity of a synchrony measure, creating artificial interactions using randomly shuffled pairs or data shuffling within a time series is commonly used (Bernieri, Reznick, & Rosenthal, 1988; Fujiwara et al., 2020; Moulder, Boker, Ramseyer, & Tschacher, 2018). The former, known as the pseudo-synchrony experimental paradigm (Bernieri & Rosenthal, 1991), uses time series of two individuals not engaged in actual interaction with one another. The latter is now known as surrogate data generation. The rationale of such techniques is to determine a baseline synchrony level in artificial interactions makes researchers enable to accurately assess the level of synchrony in the genuine dyadic interactions. In this study, the length of interaction time was different among each negotiation task so that randomly shuffled pseudo pairs could not be created. Thus, we performed data shuffling within each time series to generate surrogate data, which is considered as a time series equivalent of a randomization/permutation test (Moulder et al., 2018).

5. Method

5.1. Experimental design and participants

To investigate the role of synchrony in human-avatar communication in negotiation situations, this study employed a factorial experimental design in which the setting of negotiation (integrative, distributive) was manipulated. More specifically this study was framed as a computer-mediated multi-issue bargaining task with an avatar. The goal of the task was to divide items between both parties. Participants were instructed to negotiate with an avatar in order to come to an agreement, the maximum interaction time for this task was 10 min. The avatar was named "Sam" for both the male and female version of the avatar. There were two sets of items, the first set consisted of one antique clock, two porcelain plates and three chairs, the second set contained one painting, two lamps and three crates of LP records. Participants were informed of the relative value of each item before starting the interaction, the specific values of these items were determined by the setting of the study. In the distributive setting, items were worth the same amount for both participant and avatar: A single chair/crate of records was worth twice as much as both plates/lamps, while the clock/painting was worth almost nothing. In the integrative condition, the item value differed between the participant and the avatar. The value for participants was the same as in the distributive condition, but for the agent, the value of the chairs/record crates and plates/lamps were reversed. Participants were not told the avatar's value of items in either condition, however they could discover this during the negotiation by asking questions or observing the avatar's pattern of offers (the avatar always responded truthfully to questions about what it values). The integrative condition could lead to a win-win situation, allowing both the participant and the avatar to receive their highest value items (as opposed to the win-lose situation of a distributive condition). If no agreement was reached within the 10 min time limit, each party would only receive a single copy of their highest value item.

Participants in this study were recruited from a city on the west coast

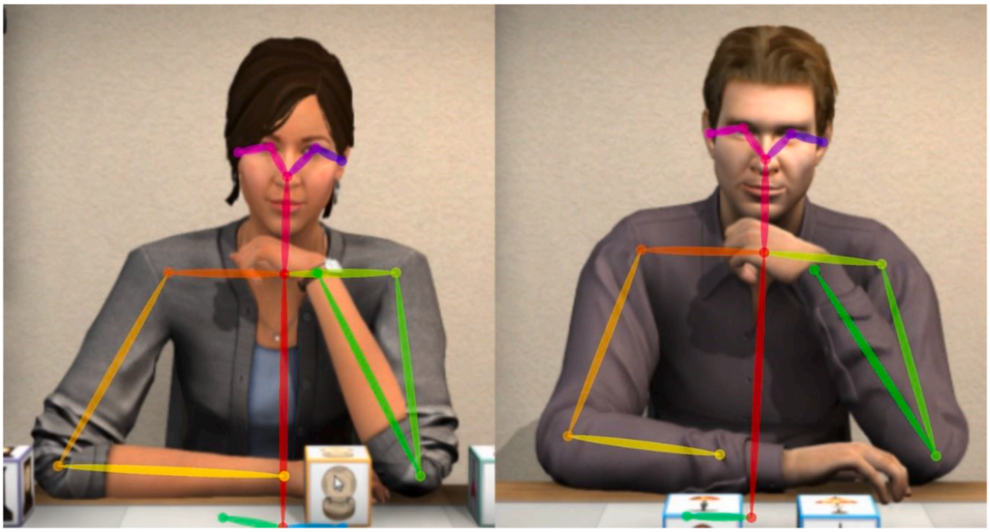

Fig. 1. Appearance of female and male avatar during the negotiation with the skeletons rendered by OpenPose overlaid on the avatars.

in the United States using online advertisements. Participants were paid $30 for the study which roughly took 1 h. The sample size of this study was $N = 176$[1] however, four participants were removed from the analysis because they failed to reach agreement. Thus, the sample analyzed was $N = 172$ ($M_{age} = 19.87$, $SD_{age} = 1.50$), which was 68% female and 32% male. For the demographics of the study 38.4% identified as African American, 9.3% as Asian, 35.5% as White/Caucasian, 13.4% as Hispanic, 3.5% as Native American, 0.6% as Native Hawaiian/Other Pacific and 7% identified as some other race.

5.2. Procedure

Before starting the study, participants signed a consent form and were instructed about the task, they also received an instruction sheet that showed them the relative value of each item. Throughout the study, participants were seated behind a table that was facing a large monitor that would display the agent. On the table, there was a mouse, in order to interact with items on screen, and a timer that would show the remaining time of the interaction. Participants were recorded by two cameras, the first camera was placed on a tripod behind the monitor. It filmed over the monitor and was angled slightly downward to record the upper body of the participant. Secondly, a small webcam was situated directly on top of the monitor, for a closer recording of the participant's face. Participants also wore a small wired microphone in order to collect high quality audio recording of their voice. During the study, the large monitor displayed the avatar seated behind a table (see Fig. 2). On this table, the items of the multi-issue bargaining task were represented as simple cubes with an image of the item.

Participants could talk to the agent without any restrictions, and they could move the cubes on the table using a mouse. The cubes could be moved either towards the avatar's side of the table or the participant's side, in order to represent an offer. The avatar would also interact with these cubes to represent its offer. The avatar was controlled by two experimenters through a graphical user interface. One experimenter controlled the agent's speech and verbal behavior, while the other controlled the avatar's nonverbal behavior such as facial expressions and gestures. The experimenters were trained in order to make the avatar behave as realistically as possible. Experimenters were seated in a separate room from the participant, but could see and hear the participant through a video feed. The experimenters were instructed to try and win the negotiation (i.e. maximize their own score).

5.3. Automated coding of synchrony

5.3.1. Generating time series data on human/avatar movement

Using video films of the negotiation, time-series bodily movement data was obtained using OpenPose (Cao et al., 2017). For avatars, the 2-D information of 10 coordinate points (i.e., eyes, nose, neck, shoulders, elbows, and hands/wrists) was used whereas 3 coordinate points (i.e., eyes and nose) were targeted for humans because many participants were videotaped with only their faces (i.e., above the chin). For missing values of the coordinates (mainly due to occlusion), the researchers applied spline interpolation using the "na.spline" function of the *zoo* package in R. The moving average technique was not applied because each estimated coordinate was well captured and not visually jittered. Then, the distance of each coordinate between frames calculated as $\sqrt{(x_{t+1} - x_t)^2 + (y_{t+1} - y_t)^2}$ was summed to obtain the information of each human/avatar movement. The sampling frequency was set to 30 Hz, which was equal to the video frame rate.

5.3.2. Calculating synchrony

To perform dynamic time warping, the "dtw" function of the *dtw* package in R was used. The default parameters of the function were used, and no locality constraints were additionally employed. Then, the distance score, the inverse to the amount of synchrony, was obtained for each dyad. In dynamic time warping, longer time-series should have greater distances because the algorithm cumulatively calculates the distance at each point of time. In this study, the Pearson's bivariate correlation between the distance and the duration of the negotiation task ($M = 322.24$ (s), $SD = 182.39$) was significantly positive ($r = 0.635$, $p < .001$). Still, the primary results (i.e., the significant results of each hypothesis) were not changed when controlling the task duration.

5.3.3. Surrogate data generation and calculating synchrony

To investigate the existence of synchrony, creating artificial interactions using randomly shuffled pseudo pairs or data shuffling within a time series is commonly used (Bernieri et al., 1988; Fujiwara et al., 2020; Moulder et al., 2018). The former, known as the

[1] The sample size of the original data collection was $N = 248$ ($n = 92$ for the integrative condition, $n = 156$ for the distributive condition). During the debriefing process, participants opted into specific ways in which the researchers could use their data. Some participants did not sign their initials next to the option of allowing the researchers to share their videos with collaborators from other universities. As such, these videos were not shared with one of the authors from another university who conducted the automated analyses.

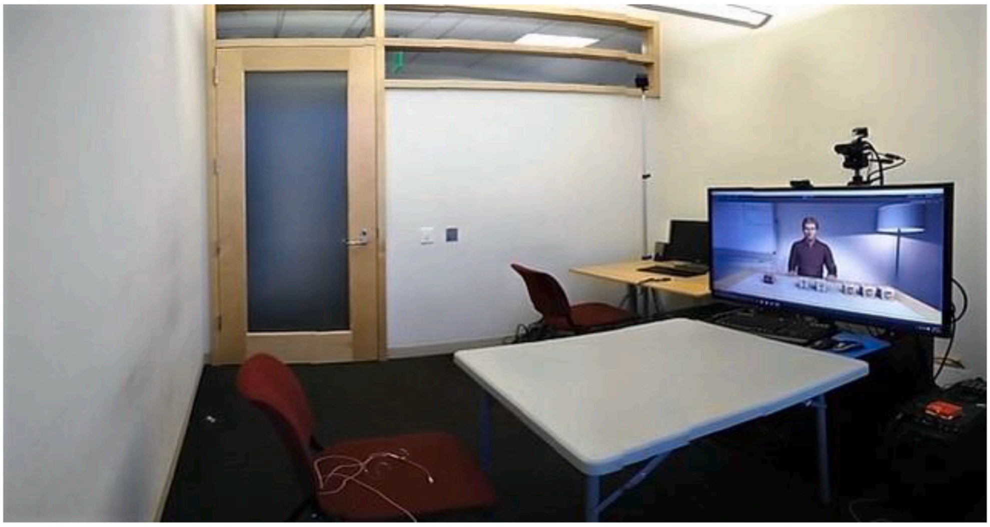

Fig. 2. The experiment room set-up from the participants' perspective.

pseudo-synchrony experimental paradigm (Bernieri & Rosenthal, 1991), uses two individuals not engaged in actual interaction with one another. The latter is now known as surrogate data. The rationale of such techniques is to determine a baseline synchrony level in artificial interactions makes researchers enable to accurately assess the level of synchrony in the genuine dyadic interactions.

In this study, the length of interaction time was different among each negotiation task so that randomly shuffled pseudo pairs could not be created. Thus, we performed data shuffling within each time series to generate surrogate data, which is considered as a time series equivalent of a randomization/permutation test (Moulder et al., 2018). For each pair of time series (H, A), each data point was randomly shuffled to create a new time series (H^s, A^s). By shuffling data this way, all of the time-dependent properties in this series are destroyed although H^s and A^s retain the same mean, variance, and distribution as H and A, respectively. The distance score between H^s and A^s was calculated via dynamic time warping to compare that in the genuine interaction (i.e., H and A).

To compute synchrony, we performed dynamic time warping using the "dtw" function of the *dtw* package in R. The default parameters of the function were used, and no locality constraints were additionally employed. Then, the distance score, the inverse to the amount of synchrony, was obtained for each dyad in the genuine interaction (i.e., H and A) and surrogate data (i.e., H^s, A^s), respectively.

5.4. Questionnaires

After finishing the negotiation, participants filled out a survey about their interaction with the avatar. Participants were asked their general impressions on the avatar ("What was your impression of Sam?") and then were presented with the following 7-point semantic differentials:

Uncooperative/Cooperative, Unfriendly/Friendly, Reactive/Strategic, Dishonest/Honest.

Selfish/Fair, Ineffective/Effective, Poor communicator/Good communicator and Negative/Positive. For the analysis on the impression of the avatar, we took the mean score of this survey as the impression rating (8 items; $\alpha = 0.88$).

6. Results

6.1. Difference between the genuine and surrogate data

Hypothesis 1 predicted that the participants would synchronize their movement with the non-human avatar. To test the existence of synchrony, surrogate data was created using data shuffling. The results of the comparison between the genuine and surrogate data showed that the distance was significantly smaller in the genuine human-avatar dyad ($M = 42319.36$, $SD = 36645.51$) compared to the dyad with shuffled surrogate data[2] ($M = 48849.77$, $SD = 38508.15$), $t(170) = 16.09$, $p < .001$, d = 1.23. Thus, H1 was supported.

6.2. The impact of the experimental manipulation on synchrony

Hypothesis 2 predicted that synchrony would be higher in integrative (cooperative) condition than the distributive condition. The result of a separate t-test revealed that the distance score, calculated via dynamic time warping, in the integrative condition ($M = 17631.63$, $SD = 9136.28$) was significantly lower than that in the distributive condition ($M = 60457.28$, $SD = 38649.79$), $t(111.44) = 10.57$, $p < .001$, d = 1.42. This means that, as H2 predicted, participants in the cooperative condition exhibited more synchrony.

6.3. Synchrony and impression to avatar

Hypothesis 3 predicted that synchrony with non-human avatars will lead to a favorable impression of the avatar. Pearson's bivariate correlation was significant and negative ($r = -.35$, $p < 0.001$), which indicates synchrony increased the favorable impression of the avatar as predicted. However, similar to the synchrony measure, the impression score significantly corresponded to the negotiation setting; the avatar in the integrative condition ($M = 5.78$, $SD = 0.98$) was perceived more favorably than in the distributive condition ($M = 5.17$, $SD = 1.23$), $t(133.22) = 3.14$, $p = .002$, d = 0.53, whereas the interaction effect of synchrony and the negotiation setting was not significant ($p = .118$). Thus, to incorporate the impact of the experimental manipulation, a mediation analysis with a bootstrapping method (resampling = 5000) was performed using the "sem" function of the *lavaan* package in R. The result showed the indirect effect was significant ($\beta = 0.203$, $SE = 0.064$, $p < .001$) and the impact of the negotiation setting on impression of avatar was fully mediated by synchrony (Fig. 3).

Therefore, H3 was supported.

[2] The effect size of the paired t-test was calculated as $\frac{|m_1 - m_2|}{\sqrt{s_1^2 + s_2^2 - 2r_{12}s_1s_2}}$ where m, s, r represents *Mean*, *SD*, and correlation, respectively.

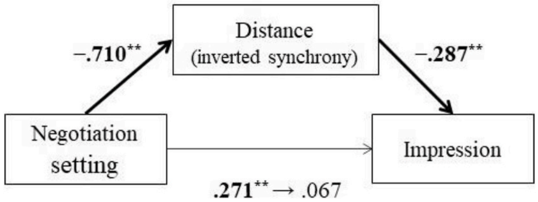

Fig. 3. Synchrony mediates the impact of experimental manipulation on impression to avatar. Note. Negotiation setting is binarily coded: integrative (1), distributive (0). All the estimates were standardized (** $p < .01$).

6.4. Synchrony and negotiation outcomes

As a research question, we explored whether synchrony leads to better negotiation outcomes for the human player. Since the negotiation setting is supposed to constrain how the participants make a decision greatly, a separate *t*-test was firstly performed on the participant's and avatar's score. The results showed the player's score was significantly lower in the integrative condition ($M = 47.57$, $SD = 8.18$) than the distributive condition ($M = 56.94$, $SD = 6.80$), $t(135.75) = 7.92$, $p < .001$, d = 1.26, while the avatar's score was not significantly different between the integrative condition ($M = 67.78$, $SD = 4.19$) and the distributive condition ($M = 66.79$, $SD = 6.35$), $t(166.23) = 1.23$, $p = .222$, d = 0.18.

Then, to investigate the association of synchrony and the negotiation outcomes, the interaction effect of synchrony and the setting was examined. The results revealed a significant interaction effect for the participant's score ($\beta = 0.823$, $SE = 0.194$, $p < .001$) and the avatar's score ($\beta = 1.076$, $SE = 0.225$, $p < .001$). The simple slope test indicated synchrony (i.e., the smaller distance) resulted in a lower player's score and a higher avatar's score in the integrative condition. However, synchrony did not have a significant effect in the distributive condition (Fig. 4).[3] As for the RQ, the results showed that participants' willingness to engage in synchrony boosted the avatar-friendly decision in the integrative negotiation where they could accomplish a win-win deal. Instead, synchrony had no impact on their outcomes in the zero-sum negotiation.

7. Discussion

The purpose of this research was to examine whether human negotiators would synchronize their movements when working with non-human avatars and if so, whether that would affect their perceptions of their negotiations. Three hypotheses were supported: participants synchronized their movements with the movements of their non-human negotiation partner (H1), greater synchrony was observed when participants engaged in an integrative negotiation compared to a distributive negotiation (H2), and participants that engaged in synchrony reported greater affiliation with their non-human partner (H3). For the RQ, synchrony led to giving more to the agent in an integrative negotiation whereas it had no significant impact on the outcomes in a distributive negotiation.

First, using the randomly shuffled virtual interaction (i.e., surrogate data), we confirmed that the genuine human-avatar interaction exhibited greater synchrony, which supports the existing findings in user-system synchrony (e.g., Ansermin et al., 2017; Hofree et al., 2014). Interpersonal synchrony is a fundamental activity that forms the basis of social and biological development (Burgoon et al., 2014), which is so pervasive that humans exhibit synchrony to even non-human systems. However, given that the experimenters controlled the avatar's verbal and nonverbal behavior and tried to make the avatar behave as realistically as possible, it would not be possible to strictly mention whether the participants or the avatar (i.e., the experimenters behind the avatar) were initiating synchrony.

Second, supporting the previous studies that have demonstrated that synchrony can break down when the competitive aspects of negotiation are emphasized (Carnevale et al., 1981; Lanzetta & Englis, 1989), we found that synchrony was lower in distributive negotiations (where participants' interests are in conflict) compared with integrative negotiations (where participants hold complementary interests). This difference could be strategic. Establishing a positive relationship has been argued to help partners discover win-win solutions and thus displaying synchrony and developing rapport can help parties discover integrative solutions (Carnevale & Isen, 1986). But as distributive negotiations are zero-sum (i.e., there is no opportunity to grow the pie), there is presumably less incentive to creating a positive relationship. This is consistent with human-human interactions and suggests that, as Giles' (2016) CAT and Dunbar et al.'s (2020) strategic synchrony hypothesis would predict, humans are using the synchrony strategically in order to achieve more favorable outcomes, not simply synchronizing naturally as a result of being in an interaction with another being.

Third, regardless of negotiation settings, synchrony led to greater affiliation with their non-human partner. Numerous studies emphasized that synchrony works as a social bond (Fujiwara et al., 2020) such that it is often associated with increased affiliation (Hove & Risen, 2009) and rapport (Tickle-Degnen & Rosenthal, 1990). It is interesting to note that the findings from human-human interaction were also highly consistent in the human-avatar interactions studied here. In addition, the finding supports the claim that synchrony with a machine (i.e., userto-system alignment) reflects the human's strategic attempts (Bergmann et al., 2015). It seems that the participants intentionally aligned to establish a prosocial relationship with the machine partner and obtain beneficial outcomes. Then, the achievement of synchrony signals that a good relationship had been established, which led to a greater sense of affiliation.

Fourth, synchrony led to an avatar-friendly decision in an integrative negotiation. A previous study demonstrated that synchrony facilitated cooperation in an economic game even when the situation required personal sacrifice (Wiltermuth & Heath, 2009). Rapport formed through synchrony seems to have encouraged participants to make self-sacrificing decisions. Alternatively, synchrony had no impact on the outcomes in a distributive negotiation. This might be attributed to the zero-sum game setting itself. Given the findings of the integrative condition, the participants experiencing synchrony might have been tempted to give more to the avatar. However, in the distributive condition, such a decision leads directly to their own loss. Thus, since the game setting has strongly dictated how decisions are made, the impact of synchrony might have been offset.

Overall, these findings reinforce the importance of synchrony in human-machine interactions. Here, we demonstrated that human-machine synchrony predicted positive subjective feelings as well as the outcomes that were negotiated. Our findings further suggest that people are strategic in their willingness to engage in synchrony, for example, only synchronizing movements when there appeared to be material benefits to this behavior.

Although these findings give insights into human social behavior, they also raise important practical and ethical questions for agent design. Our results complement a growing body of research that anthropomorphic interfaces can use subtle nonverbal signals to shape both perceptions and behavior (e.g., see Lugrin, Pelachaud & Traum, 2021). Some of these findings have obvious societal benefits such as enhancing physical and mental health (Bickmore & Pfeifer, 2008; Lucas et al., 2017). But other uses may be more problematic. For example, we have found that agents can extract greater concessions from a human

[3] Mediation analysis with a bootstrapping method (resampling = 5000) was also performed, which revealed that synchrony did not mediate the impact of the negotiation setting on the participant's score (indirect effect; $\beta = -0.070$, $SE = 0.053$, $p = .188$) and the avatar's score (indirect effect; $\beta = 0.081$, $SE = 0.078$, $p = .298$).

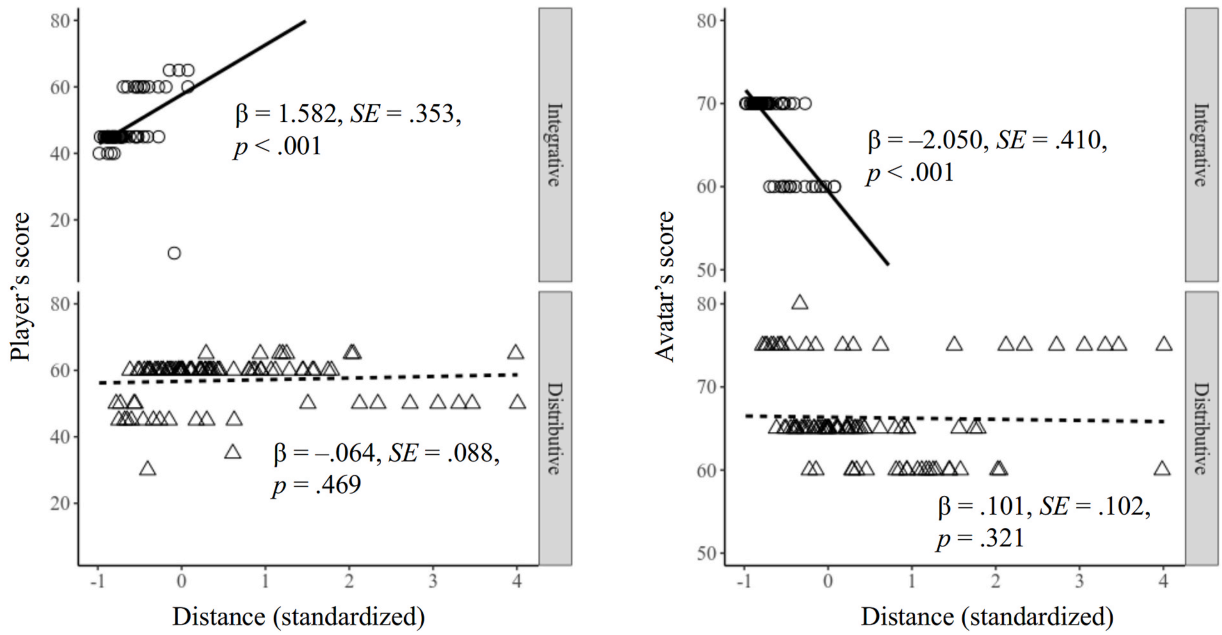

Fig. 4. The interaction effect of synchrony and the negotiation setting on the negotiation outcome. Note: Left: Player's score. Right: Avatar's score.

negotiation partner by strategically using synthetic emotional expressions (de Melo, Carnevale, & Gratch, 2011) and potential consumers would want to own such an agent if it helped them manipulate others for their own personal gain (Mell, Lucas, Mozgai, & Gratch, 2020), The field of artificial intelligence is becoming more aware of the need to work through ethical principles to guide the development of such technology (Chatila & Havens, 2019). Our findings lend greater urgency to such efforts.

8. Conclusions

In sum, this study revealed not only that humans coordinate their behavior with nonhuman avatars, but that they do so strategically in order to achieve more favorable outcomes. As non-human avatars become more realistic over time, we expect to see more humanlike interactions. This research suggests that synchrony can be used to establish rapport and create positive outcomes for those interactions.

Author contribution

Ken Fujiwara: Conceptualization, Methodology, Software, Formal analysis, Data Curation, Writing - Original Draft, Visualization. Rens Hoegen: Methodology, Formal analysis, Investigation, Writing - Review & Editing. Jonathan Gratch: Conceptualization, Investigation, Writing - Original Draft, Supervision, Resources. Norah Dunbar: Conceptualization, Writing - Original Draft, Supervision.

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References

Ansermin, E., Mostafaoui, G., Sargentini, X., & Gaussier, P. (2017). Unintentional entrainment effect in a context of Human Robot Interaction: An experimental study. Aug.-1 Sept. 2017. In *Paper presented at the 2017 26th IEEE international symposium on robot and human interactive communication* (Vol. 28). RO-MAN).

Bailenson, J. N., & Yee, N. (2005). Digital chameleons: Automatic assimilation of nonverbal gestures in immersive virtual environments. *Psychological Science, 16*(10), 814–819. https://doi.org/10.1111/j.1467-9280.2005.01619.x

Balliet, D., Wu, J., & De Dreu, C. K. W. (2014). Ingroup favoritism in cooperation: A metaanalysis. *Psychological Bulletin, 140*(6), 1556–1581. https://doi.org/10.1037/a0037737

Bell, L., Gustafson, J., & Heldner, M. (2003). Prosodic adaptation in human-computer interaction. Paper presented at the *Proceedings of ICPHS*.

Bergmann, K., Branigan, H. P., & Kopp, S. (2015). Exploring the alignment space – lexical and gestural alignment with real and virtual humans. *Frontiers in ICT, 2*, 7. https://doi.org/10.3389/fict.2015.00007

Berndt, D. J., & Clifford, J. (1994). Using dynamic time warping to find patterns in timeseries. In *Proceedings of the workshop on knowledge discovery in database* (pp. 359–370).

Bernieri, F. J., Reznick, J. S., & Rosenthal, R. (1988). Synchrony, pseudosynchrony, and dissynchrony: Measuring the entrainment process in mother-infant interactions. *Journal of Personality and Social Psychology, 54*(2), 243–253. https://doi.org/10.1037/0022- 3514.54.2.243

Bernieri, F. J., & Rosenthal, R. (1991). Interpersonal coordination: Behavior matching and interactional synchrony. In R. Feldman, & B. Rime (Eds.), *Fundamentals of nonverbal behavior: Studies in emotion & social interaction* (pp. 401–432). Cambridge University Press.

Bickmore, T., & Pfeifer, L. (2008). *Relational agents for antipsychotic medication adherence*. Florence, Italy: Paper presented at the CHI'08 workshop on Technology in Mental Health.

Bohnet, I., & Frey, B. S. (1999). Social distance and other-regarding behavior in dictator games: Comment. *The American Economic Review, 89*(1), 335–339. https://doi.org/10.1257/aer.89.1.335

Branigan, H. P., Pickering, M. J., Pearson, J., & McLean, J. F. (2010). Linguistic alignment between people and computers. *Journal of Pragmatics, 42*(9), 2355–2368. https://doi.org/10.1016/j.pragma.2009.12.012

Burgoon, J. K., Dunbar, N. E., & Giles, H. (2017). Interaction coordination and adaptation. In J. K. Burgoon, N. Magnenat-Thalmann, M. Pantic, & A. Vinciarelli (Eds.), *Social signal processing* (pp. 78–96). Cambridge University Press.

Burgoon, J. K., Dunbar, N. E., & White, C. (2014). Interpersonal adaptation. In C. R. Berger (Ed.), *Interpersonal communication* (pp. 225–248). Berlin: De Gruyter Mouton Publisher.

Burgoon, J. K., Stern, L. A., & Dillman, L. (1995). *Interpersonal adaptation: Dyadic interaction patterns*. Cambridge University Press.

Burnham, T., McCabe, K., & Smith, V. L. (2000). Friend-or-foe intentionality priming in an extensive form trust game. *Journal of Economic Behavior & Organization, 43*(1), 57–73. https://doi.org/10.1016/S0167-2681(00)00108-6

Cao, Z., Simon, T., Wei, S. E., & Sheikh, Y. (2017). Realtime multi-person 2D pose estimation using part affinity fields. In *Proceedings of the IEEE conference on computer vision and pattern recognition* (pp. 7291–7299).

Card, S. K., Moran, T. P., & Newell, A. (1983). *The psychology of human-computer interaction*. Lawrence Erlbaum.

Carnevale, P. J., & Isen, A. M. (1986). The influence of positive affect and visual access on the discovery of integrative solutions in bilateral negotiation. *Organizational Behavior and Human Decision Processes, 37*, 1–13. https://doi.org/10.1016/0749-5978(86)90041-5

Carnevale, P. J., Pruitt, D. G., & Seilheimer, S. D. (1981). Looking and competing: Accountability and visual access in integrative bargaining. *Journal of Personality and Social Psychology, 40*(1), 111–120. https://doi.org/10.1037/0022-3514.40.1.111

Chatila, R., & Havens, J. C. (2019). The IEEE global initiative on ethics of autonomous and intelligent systems. In M. I. Aldinhas Ferreira, J. Silva Sequeira, G. Singh Virk, M. O. Tokhi, & E. E. Kadar (Eds.), *Robotics and well-being* (pp. 11–16). Cham: Springer International Publishing.

Choi, M., Kornfield, R., Takayama, L., & Mutlu, B. (2017, May). Movement matters: Effects of motion and mimicry on perception of similarity and closeness in robot-mediated communication. In *Proceedings of the 2017 CHI conference on human factors in computing systems* (pp. 325–335).

Coco, M. I., & Dale, R. (2014). Cross-recurrence quantification analysis of categorical and continuous time series: An R package. *Frontiers in Psychology, 5*, 510. https://doi.org/10.3389/fpsyg.2014.00510

Drolet, A. L., & Morris, M. W. (2000). Rapport in conflict resolution: Accounting for how faceto-face contact fosters mutual cooperation in mixed-motive conflicts. *Journal of Experimental Social Psychology, 36*, 26–50. https://doi.org/10.1006/jesp.1999.1395

Dunbar, N. E., Giles, H., Bernhold, Q., Adams, A., Giles, M., Zamanzadeh, N., et al. (2020). Strategic synchrony and rhythmic similarity in lies about ingroup affiliation. *Journal of Nonverbal Behavior, 44*, 153–172. https://doi.org/10.1007/s10919-019-00321-2

Fehr, E., & Schmidt, K. M. (1999). A theory of fairness, competition, and cooperation. *Quarterly Journal of Economics, 114*(3), 817–868. https://doi.org/10.1162/003355399556151

Fujiwara, K., Bernhold, Q. S., Dunbar, N. E., Otmar, C. D., & Hansia, M. (2021). Comparing manual and automated coding methods of nonverbal synchrony. *Communication Methods and Measures, 15*(2), 103–120. https://doi.org/10.1080/19312458.2020.1846695

Fujiwara, K., Kimura, M., & Daibo, I. (2020). Rhythmic features of movement synchrony for bonding individuals in dyadic interaction. *Journal of Nonverbal Behavior, 44*(1), 173–193. https://doi.org/10.1007/s10919-019-00315-0

Giles, H. (Ed.). (2016). *Communication accommodation theory: Negotiating personal relationships and social identities across contexts*. Cambridge University Press.

Gratch, J., & Lucas, G. M. (2021). Rapport between humans and socially interactive agents. In B. Lugrin, C. Pelachaud, & D. Traum (Eds.), *Handbook of socially interactive agents* (pp. 433–462). ACM Books.

Gratch, J., Wang, N., Gerten, J., & Fast, E. (2007). *Creating rapport with virtual agents*. Paris, France: Paper presented at the 7th International Conference on Intelligent Virtual Agents.

Hofree, G., Ruvolo, P., Bartlett, M. S., & Winkielman, P. (2014). Bridging the mechanical and the human mind: Spontaneous mimicry of a physically present android. *PLoS One, 9*(7), Article e99934. https://doi.org/10.1371/journal.pone.0099934

Hove, M. J., & Risen, J. L. (2009). It's all in the timing: Interpersonal synchrony increases affiliation. *Social Cognition, 27*(6), 949–960. https://doi.org/10.1521/soco.2009.27.6.949

Iio, T., Shiomi, M., Shinozawa, K., Shimohara, K., Miki, M., & Hagita, N. (2015). Lexical entrainment in human robot interaction. *International Journal of Social Robotics, 7*(2), 253–263. https://doi.org/10.1007/s12369-014-0255-x

Knoblich, G., Butterfill, S., & Sebanz, N. (2011). Psychological research on joint action. Psychology of learning and motivation. In *Advances in research and theory* (Vol. 54, pp. 59–101). New York, NY: Elsevier.

Kühne, V., Rosenthal-von der Pütten, A. M., & Krämer, N. C. (2013). *Using linguistic alignment to enhance learning experience with pedagogical agents*. Berlin, Heidelberg: The Special Case of Dialect.

Lanzetta, J. T., & Englis, B. G. (1989). Expectations of cooperation and competition and their effects on observers' vicarious emotional responses. *Journal of Personality and Social Psychology, 45*, 543–554. https://doi.org/10.1037/0022-3514.56.4.543

Lucas, G. M., Rizzo, A., Gratch, J., Scherer, S., Stratou, G., Boberg, J., et al. (2017). Reporting mental health symptoms: Breaking down barriers to care with virtual human interviewers. *Frontiers in Robotics and AI, 4*, 51. https://doi.org/10.3389/frobt.2017.00051

Lugrin, B., Pelachaud, C., & Traum, D. (Eds.). (2021). *Handbook on socially interactive agents*. B. ACM Press.

Mell, J., Lucas, G., Mozgai, S., & Gratch, J. (2020). The effects of experience on deception in human-agent negotiation. *Journal of Artificial Intelligence Research, 68*, 633–660.

de Melo, C., Carnevale, P. J., & Gratch, J. (2011). *The effect of expression of anger and happiness in computer agents on negotiations with humans*. Taipei, Taiwan: Paper presented at the Tenth International Conference on Autonomous Agents and Multiagent Systems.

de Melo, C., Carnevale, P. J., & Gratch, J. (2014). *Social categorization and cooperation between humans and computers*. Québec City, Canada: Paper presented at the 36th Annual Meeting of the Cognitive Science Society.

de Melo, C., Gratch, J., & Carnevale, P. J. (2015). Humans versus computers: Impact of emotion expressions on people's decision making. *IEEE Transactions on Affective Computing, 6*(2), 127–136.

Miles, L. K., Lumsden, J., Flannigan, N., Allsop, J. S., & Marie, D. (2017). Coordination matters: Interpersonal synchrony influences collaborative problem-solving. *Psychology, 8*, 1857–1878. https://doi.org/10.4236/psych.2017.811121

Moulder, R. G., Boker, S. M., Ramseyer, F., & Tschacher, W. (2018). Determining synchrony between behavioral time series: An application of surrogate data generation for establishing falsifiable null-hypotheses. *Psychological Methods, 23*(4), 757–773. https://doi.org/10.1037/met0000172

Oviatt, S., Darves, C., & Coulston, R. (2004). Toward adaptive conversational interfaces: Modeling speech convergence with animated personas. *ACM Transactions on Computer-Human Interaction, 11*(3), 300–328. https://doi.org/10.1145/1017494.1017498

Paxton, A., & Dale, R. (2013). Frame-differencing methods for measuring bodily synchrony in conversation. *Behavior Research Methods, 45*(2), 329–343. https://doi.org/10.3758/s13428-012-0249-2

von der Pütten, A. M., Hoffmann, L., Klatt, J., & Krämer, N. C. (2011). *Quid pro Quo? Reciprocal self-disclosure and communicative accomodation towards a virtual interviewer*. Berlin, Heidelberg: Paper presented at the International Workshop on Intelligent Virtual Agents.

Ramseyer, F. T. (2020). Motion Energy Analysis (MEA). A primer on the assessment of motion from video. *Journal of Counseling Psychology, 67*(4), 536–549. https://doi.org/10.1037/cou0000407

Ramseyer, F., & Tschacher, W. (2011). Nonverbal synchrony in psychotherapy: Coordinated body movement reflects relationship quality and outcome. *Journal of Consulting and Clinical Psychology, 79*(3), 284–295. https://doi.org/10.1037/a0023419

Reeves, B., & Nass, C. I. (1996). *The media equation: How people treat computers, television, and new media like real people and places*. Cambridge university press.

Rennung, M., & Göritz, A. S. (2016). Prosocial consequences of interpersonal synchrony: A meta-analysis. *Zeitschrift für Psychologie, 224*, 168–189. https://doi.org/10.1027/21512604/a000252

Schoenherr, D., Paulick, J., Worrack, S., Strauss, B. M., Rubel, J. A., Schwartz, B., et al. (2019). Quantification of nonverbal synchrony using linear time series analysis methods: Lack of convergent validity and evidence for facets of synchrony. *Behavior Research Methods, 51*(1), 361–383. https://doi.org/10.3758/s13428-018-1139-z

Tickle-Degnen, L., & Rosenthal, R. (1990). The nature of rapport and its nonverbal correlates. *Psychological Inquiry, 1*(4), 285–293. https://doi.org/10.1207/s15327965pli0104_1

Wiltermuth, S. S., & Heath, C. (2009). Synchrony and cooperation. *Psychological Science, 20*(1), 1–5. https://doi.org/10.1111/j.1467-9280.2008.02253.x

Wood, C., Caldwell-Harris, C., & Stopa, A. (2018). The rhythms of discontent: Synchrony impedes performance and group functioning in an Interdependent coordination task. *Journal of Cognition and Culture, 18*(1–2), 154–179. https://doi.org/10.1163/15685373-12340028