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ORIGINAL PAPER

Nonverbal Synchrony and Complementarity in Unacquainted Same-Sex Dyads: A Comparison in a Competitive Context

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Abstract Research on interpersonal synchronization deals with the coordination of behavior, cognition and affect within interacting individuals. The phenomenon of synchronization has been explored in many settings and numerous definitions have emerged. The purpose of this study was to compare nonverbal synchrony (based on overall body movement) with the concept of complementarity (based on interpersonal theory) in a competitive context. We examined 40 previously unacquainted same-sex dyads (21 female, 19 male; mean age = 22.81). Dyads underwent a 15-min videotaped competitive role-play. Nonverbal synchrony was quantified by a frame-differencing method, and complementarity by a joystick tracking method. Results revealed that dyads behaved in a synchronous and complementary manner. We found that nonverbal synchrony was positively correlated with affiliation complementarity, but not dominance complementarity. The present study compared nonverbal synchrony with complementarity. The link between the two concepts was small, as indicated by rather weak correlations between nonverbal synchrony and affiliation complementarity. Our results reinforce the view that competitive behavior depends on complex dyadic interactions, including nonverbal and verbal behavior.

Keywords Synchronization · Nonverbal · Complementarity · Interpersonal theory · Competition

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Introduction

The phenomenon of interpersonal synchronization has been shown to be relevant in a growing body of research. Predominantly, studies have focused on dyadic interactions, such as mother–child (Leclère et al. 2014), patient–psychotherapist (Ramseyer and Tschacher 2014), or student–teacher interactions (Bernieri 1988; Pennings et al. 2014). Across these different contexts, being synchronized has frequently been shown to be associated with positive interactional outcomes, such as liking, similarity, feelings of closeness, cooperation, helping, and goal-oriented behavior (Chartrand and Lakin 2013; Dunbar et al. 2014; Kim 2015; Vicaria and Dickens 2016). Due to the wide range of application areas, numerous definitions and related terms have emerged (e.g., synchrony, mimicry, reciprocity, complementarity). Different forms of synchronization can be distinguished according to its dynamics (posture vs. movement), contextual cues (e.g., expressions of emotions, movement), and the nature of time series it is computed on (e.g., movement or physiology; Karvonen et al. 2016). Consequently, along with the many different operationalizations of the phenomenon that have emerged, little is known regarding how they are related to each other. In addition to previous research, which concentrated largely on a specific form of synchronization, the purpose of this paper is to compare two different forms of dynamic synchronization—nonverbal synchrony and complementarity—in the context of same-sex competition.

Nonverbal Synchrony

Here, as one concept of synchronization, *nonverbal synchrony* is conceptualized in accordance with Ramseyer and Tschacher (2011). In this sense, the term refers to the coordinated overall body movement of two interacting individuals, which is automatically measured by so-called frame-differencing methods (Paxton and Dale 2013b). The theory of embodiment provides a theoretical framework for the mechanisms of overall body movement synchrony (Tschacher and Bergomi 2011). Broadly speaking, embodiment emphasizes the strong coupling of mental and affective processes with bodily processes. On an individual level, the theory of embodiment states that the motor system and cognitive-affective system mutually influence each other, building an interactive feedback system (Koch 2011). This notion has received support from a variety of body feedback experiments (for a review see Hatfield et al. 1992). For instance, Riskind (1984) manipulated participants' sitting positions (slumped vs. upright) and observed that participants in the slumped condition recalled more negative life events.

As reviewed by Fuchs and Koch (2014), body expressions interact with the cognitive-affective system not only *within* a person, but also *between* persons. In other words, the body feedback system of one person affects and is affected by the body feedback system of another. This rationale can be extended to an evolutionary perspective, which highlights the relevance of receiving cues about the intentions of others (Feldman 2012). In empirical terms, a higher degree of interpersonal body coordination has been linked to beneficial relationship outcomes (Chartrand and Lakin 2013). Moreover, studies in the context of psychotherapy and psychopathology (e.g., Kupper et al. 2015; Ramseyer and Tschacher 2014) showed that nonverbal synchrony was positively related to therapy success and fewer symptoms.

In the context of competitive interactions, however, only one study, by Tschacher et al. (2014), has explicitly addressed how competition affects nonverbal synchrony. The authors found that nonverbal synchrony was present in a competitive and a fun task condition, and,

to a lower extent, in a cooperative condition. They noted that the high amount of nonverbal synchrony in the competition condition was somewhat surprising, as another study indicated that a debate may disrupt nonverbal synchrony (Paxton and Dale 2013a). Moreover, nonverbal synchrony and positive affect were particularly closely connected in the competitive condition. This effect was interpreted as a consequence of the higher emotional arousal in the competition condition compared to the fun and cooperative task.

Complementarity

The most critical issue in assessing dyadic coordination by overall body synchrony is that qualitative aspects of interactional behavior are not captured. That is, the overall body movement provides little information about the emotions being expressed (e.g., smiling or anger). To address this very concern of synchronization, one suitable and frequently used framework is interpersonal theory and its concept of *complementarity* (Carson 1969; Kiesler 1983).

Interpersonal theory posits that most interpersonal behavior can be captured along the two orthogonal dimensions of dominance–submissivity and friendliness–hostility, which constitute the interpersonal circumplex (see Fig. 1). In detail, the radial position describes the type of interpersonal behavior (e.g., dominant/submissive/friendly/hostile) and the distance from the middle of the circle describes the intensity of interpersonal behavior (e.g., moderately dominant vs. highly dominant; Wiggins et al. 1989). Complementarity refers to the extent to which people interacting fit with each other regarding their dominance- and affiliation-related behavior (Tracey 1994). In detail, high *affiliation complementarity* is achieved when the affiliation of one member of a dyad is similar to the affiliation of the other member. In contrast, high *dominance complementarity* is reflected by reciprocity. That is, dominance in one dyad member is accompanied by submissiveness

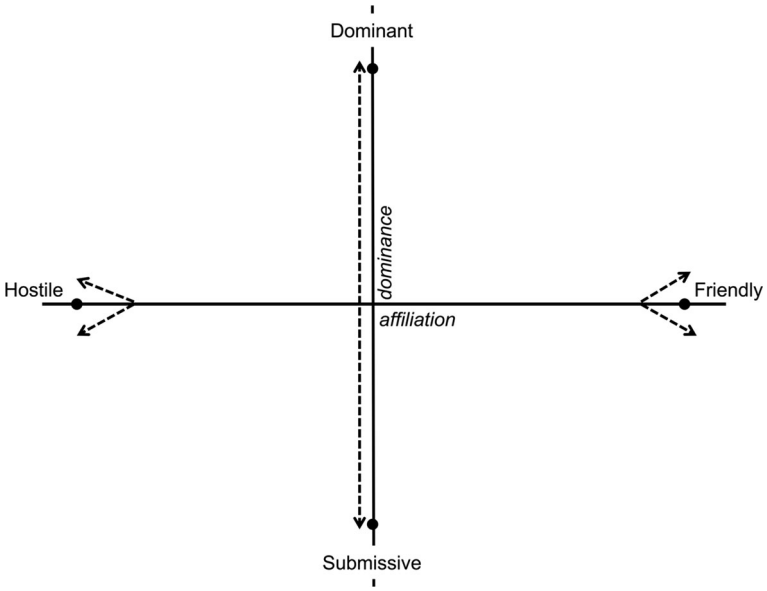

Fig. 1 Circumplex structure with the two main dimension dominance and affiliation [in italics; adapted from Carson (1969) and Kiesler (1983)]. Dashed lines with arrows indicate complementarity responses

in the other dyad member. Similar to the concept of nonverbal synchrony, complementary "assumes that every behavior carries information regarding how the other is to respond, and thus each behavior elicits or constrains subsequent behavior from others" (Tracey 1994, p. 864).

Interpersonal theorists (e.g., Kiesler 1983) suggest that dominance and affiliation complementarity is related to the experience of relationship satisfaction. As reviewed by Markey et al. (2010), this notion has received empirical support for the dimension of affiliation. With regard to the dimension of dominance, however, results have been mixed, probably due to methodological aspects (Markey et al. 2010). To the best of our knowledge, so far, there have been no analyses of complementarity in the context of competition of same-sex dyads.

Summary

To summarize, there is considerable research suggesting that nonverbal synchrony and complementarity are each associated with positive relationship outcomes. However, research on how the phenomenon of synchronization is associated with competitive behavior is lacking, despite the fact that competitive behavior and its outcomes have been extensively discussed in the psychological literature (Lee 2008; Vaillancourt 2013; Windle 1994). Moreover, research on negotiation has provided interesting results in the context of imitation (the so-called chameleon effect; Chartrand and Bargh 1999; Swaab et al. 2011). Therefore, we focused our comparative approach on the phenomenon of synchronization in a competitive context of a debate.

The hypotheses of the present study were threefold. First, we hypothesized that nonverbal synchrony and complementarity are present in a verbal competitive task. Second, we expected complementarity to be positively associated with nonverbal synchrony. Third, we expected nonverbal synchrony and complementarity to be negatively associated with the time needed to debate and to be higher in groups in which one individual wins, compared to other competition outcomes.

Method

Participants

The present study analyzed data from a larger study investigating intra- and inter-individual responses to acute laboratory stressors. Eighty healthy participants ($n_{\text{women}} = 42$) were recruited via personal communication, flyers, and announcements in seminars, lectures, and buildings of the University of Zurich and the Swiss Federal Institute of Technology.

The inclusion criterion was an age between 18 and 35 years. Exclusion criteria were pregnancy, regular medication intake (except for hormonal contraceptives), use of medication for acute diseases within seven days prior to the examination (1 month for anti-inflammatory medication), high regular alcohol consumption ($\geq$ 3 alcoholic drinks per day), consumption of mind-altering drugs 3 months prior the examination, color blindness, and participation in other stress-related studies of our department. In a telephone-based interview, participants were screened regarding inclusion and exclusion criteria and received basic verbal information. Additionally, they were given a cover story that the

study was examining associations between cognitive capabilities, psychological constructs, and physiological measures. Thereafter, an appointment was scheduled and all information was provided in written form. Prior to participation, subjects were asked to avoid physical activity and alcohol for 24 h before the appointment, as well as to avoid excessive physical effort, caffeinated beverages, and heavy meals on the scheduled day. All sessions were conducted in the afternoon.

Participants were offered written feedback about their values at the end of the study. The study was carried out in accordance with the recommendations of the declaration of Helsinki and approved by the ethics committee of the Faculty of Arts, University of Zurich.

Study Design and Procedure

Each session consisted of randomly paired dyads of previously unacquainted individuals. The experimental procedure is visualized in Fig. 2. Upon arrival at the laboratory, each participant was assigned to an examiner. After receiving brief information about the procedure, both participants in a dyad provided informed consent, and were guided into separate rooms. Following a habituation period, the Montreal Imaging Stress Task (MIST; Dedovic et al. 2005; La Marca et al. 2011) was conducted, with participants being randomly assigned to either a stress or a control condition. The stress condition combined challenging arithmetic problems with social-evaluative threat, whereas the control condition was carried out without time pressure and social evaluation. Fifteen minutes after completion of the MIST, participants were reunited with their dyad partner and the 15-min role-play took place. Six minutes later, dyads completed an adapted version of the cold pressor test (CPT) together (see "Appendix" section for methodological description and results). At the end of the experiment, participants were debriefed about the true purpose of the study. All participants then signed a second informed consent form agreeing for their data to be used.

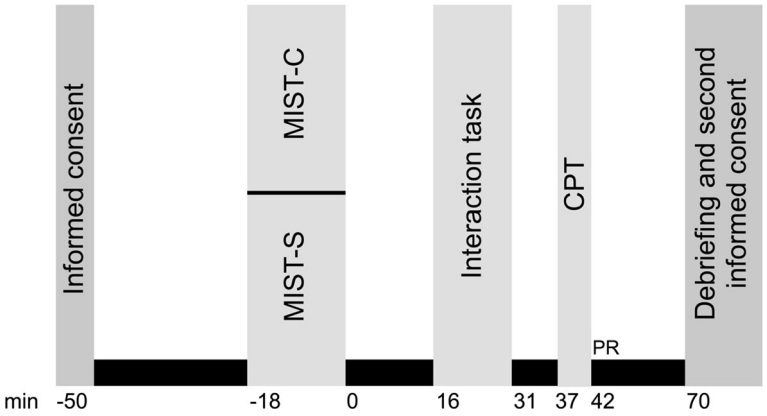

Fig. 2 Experimental timeline; *PR* pain rating, *MIST* Montreal Imaging Stress Task (stress and control condition), *CPT* Cold pressure test

Role-Play

To examine verbal and nonverbal dyadic behavior, a competitive role-play, developed from research on group dynamics (Antons and Volmerg 2000), was conducted. All role-plays were performed in same-sex dyads, with one participant having previously participated in the stress condition and one in the control condition. Before the 10-min role-play was initiated, participants were instructed that they would have to conduct a role-play in which they represented employees of a phone company. They were told that their boss had assigned a new company car to be used by one of the two employees, and that he had asked them to negotiate ownership among themselves. Both participants were randomly offered a pre-defined set of opposing arguments, with each blinded to the arguments of the other dyad member. To emphasize the competitive nature of the role-play, participants were told that both employees were very interested in obtaining the new car as it would offer more convenience and improve their status. After receiving written instructions, the video camera was turned on and both examiners left the room to enable the interaction to begin. Notably, participants were informed that they would not be interrupted before the 10-min period had elapsed and the examiners had re-entered the room.

Measures

Motion Energy Analysis (MEA)

All role-plays were recorded using a camera (JVC F1.2, JVC Corporation, Tokyo, Japan). To videotape both participants, one camera was placed in a fixed position in front of the participants, who were facing each other at an angle of approximately 130°. After termination of the study, the video files were analyzed using video-analysis software customized for motion energy analyses (MEA.app;[1] Ramseyer 2008). The MEA program quantifies all pixel changes in pre-selected regions of interest from one frame to the next. In the present study, one region of interest was determined for each participant in a dyad. These regions were non-overlapping, and covered the entire body of a participant. A threshold was adapted per dyad in accordance with the MEA default procedure (cf. Ramseyer and Tschacher 2011). Consequently, for each dyad, two time series representing the individual participants' movement activities were obtained: Higher values indicate a higher amount of whole body movement for the respective region of interest (i.e., a participant's entire body) at the respective frame change.

We then cut the time series to contain only sequences in which the role-play took place. For six dyads (15.38%), we deleted short segments of the time series (in seconds: $M = 21.52$, $SD = 3.29$, *range* 17–26) because they contained perturbations of the role-play when, for example, a participant temporarily stood up or an examiner re-entered the room to answer participants' questions. Such events would lead to spurious motion energies unrelated to the role-play task. Thereafter, all time series were truncated to equal the role-play of the dyad with the shortest length (9.5 min). Further, the time series were pre-processed as suggested by Tschacher et al. (2014): A moving average of 0.5 s was applied to reduce outliers due to signal distortion. To account for varying-sized regions of interest, all time series were finally z-standardized within each participant.

Overall nonverbal synchrony for each dyad was based on segment-wise cross-correlations of the paired time series (Boker et al. 2002). Here, the term "segment" refers to a

[1] Downloaded from www.psync.ch.

vector of sequential data points sampled from a participant's time series (equal to Boker et al.'s (2002) term "window"). The times series were cut into segments of 60 s and the cross-correlations within each segment were computed with lags up to ± 5 s, i.e., within a 10-s window. Nonverbal synchrony was then defined based on all these cross-correlations. This operationalization thus includes simultaneous correlations as well as time-lagged responses of person A to person B and responses of person B to person A—which represented the default procedure used in previous research (Tschacher et al. 2014). All cross-correlations were transformed using Fisher's Z transformation; then the absolute Z values were aggregated separately in each segment of the entire time series. Finally, the aggregated Z values of all segments were averaged across the entire time series to obtain a value of nonverbal synchrony for each dyad.

Since the duration of the actual debates differed between dyads (i.e., the time during which participants were interacting according to the examiners' instructions instead of continuing talking about other topics), nonverbal synchrony was also computed by applying the same steps exclusively for the time the dyads debated (nonverbal synchrony restricted to debate). This resulted in two nonverbal synchrony measures for each dyad, a synchrony for the truncated time series and a synchrony for the debate-only time series.

Joystick Coding and Complementarity

To assess the *dominance and affiliation time series*, two judges independently applied Sadler's joystick tracking method to the role-play video recordings (Sadler et al. 2009). That is, the judges separately rated one randomly selected member from each dyad. Upon completion, the other dyad's member was rated. By utilizing the joystick, a dot moved along the Cartesian plane, with an x-axis ranging from − 1000 (i.e., very low affiliation) to + 1000 (i.e., very high affiliation) and a y-axis ranging from − 1000 (i.e., very low dominance) to + 1000 (i.e., very high dominance). Hence, movement along the affiliation axis indicated a participant's shift in affiliation-related behaviors, whereas movement along the dominance axis indicated a participant's shift in dominance-related behaviors. The program continuously recorded (every 0.5 s) the values of both axes, resulting in a time series representing the x-axis values (i.e., affiliation) and a time series representing the y-axis values (i.e., dominance) per participant. A further detailed description of the method can be found elsewhere (Lizdek et al. 2012).

All ratings given to a specific participant were averaged across judges at each time point. On average, 1170.5 behavioral codes (i.e., 9 min, 45 s) were assessed for each participant ($SD = 29.75$; *range* 1106–1282). As suggested by Sadler et al. (2009), the first 5 s from each time series were removed to avoid "boxcar" artifacts (i.e., the movement from the joystick's resting position to the first intended rating). To obtain equal numbers of observations within each respective dyad, we further adjusted the time series to the length of the member of the dyad with the lower number of observations. Reliability was examined using the mean dominance and affiliation scores (i.e., the average of all behavioral codes given to a specific participant). Intraclass correlation coefficients of behavioral levels (average fixed raters; McGraw and Wong 1996) were $r = .86$ for dominance and $r = .67$ for affiliation, respectively. Thus, reliability was excellent for dominance and good for affiliation (cutoff values for interrater reliability: good ≥ .60, excellent ≥ .75; Cicchetti et al. 2006).

On the basis of the two time series per participant (i.e., one with affiliation values and one with dominance values), the *complementarity measures* were computed: Two measures were obtained per dyad by conducting cross-correlations (i.e., one affiliation

complementarity measure and one dominance complementarity measure). Regarding affiliation, a strong positive cross-correlation indicated high affiliation complementarity, or in other words, more similarity within the two dyad member's affiliation values. Regarding dominance, a strong negative cross-correlation indicated high dominance complementarity, or in other words, more dissimilarity within the two dyad member's dominance values. To facilitate interpretation of the complementarity measures (i.e., stronger positive cross-correlations for the affiliation and the dominance dimensions reflect higher complementarity scores), all cross-correlations based on the dominance dimension were multiplied by -1.

Additionally, to examine whether complementarity occurred simultaneously or by a leading/following pattern, cross-correlations with time lags up to $\pm$ 5 s were computed for both dimensions, dominance, and affiliation. For this examination, the cross-correlations were not computed segment-wise. The cross-correlation functions were then visually inspected for each dyad and revealed that the correlations tended to be strongest at a time lag of 0. Hence, complementarity appeared to be instantaneous rather than reflecting a leader–follower pattern. This is in line with previous work assessing complementarity by utilizing the joystick tracking method (Markey et al. 2010; Sadler et al. 2009; Sadler et al. 2015). Thus, the average amount of complementarity expressed by each dyad was based on cross-correlations with no time lag for each dyad's dominance and affiliation codes.

Similar to the procedure described for nonverbal synchrony, and in addition to the overall complementarity scores, complementarity was also computed for the time the dyads debated (complementarity restricted to debate). This procedure resulted in four complementarity measures: (1) overall dominance complementarity, (2) dominance complementarity restricted to debate, (3) overall affiliation complementarity, and (4) affiliation complementarity restricted to debate.

Data Analysis

All analyses were performed using the R 3.1.3 statistical program (R Core Team, 2016). Given that the nonverbal synchrony and complementarity values were between-dyad variables (i.e., values are the same for both dyad members and the variation is between dyads), dyad was used as the unit of analysis (Kenny et al. 2006). To examine the relationship of between-dyad variables, we computed pairwise Spearman's correlations, based on a degree of freedom $N_{\text{dyads}} - 2 = 37$ to follow up these findings. Next, robust linear regressions were computed, as implemented in the R-package robustbase (Rousseeuw et al. 2009), applying the settings recommended by Koller and Stahel (2011). This method allowed the small sample size and the non-normal distribution of the dependent variables to be taken into account (Wawrzyniak et al. 2016).

To compare groups, Welch's unequal variances t tests with fractional degrees of freedom are reported. One female dyad was excluded from all analyses due to technical recording problems leading to missing behavioral data. Therefore, all analyses were conducted with 39 (20 female, 19 male) dyads. All analyses were two-tailed, with the level of significance set at $p \leq .05$; trends are indicated by daggers.

Post-hoc Power Analysis

We conducted post hoc power analyses using G*Power 3.1.9.2 (Faul et al. 2007) to clarify the power of the present study. Power was assessed with the "multiple regression: Fixed model, R^2 deviation from zero" procedure. Since the effect sizes of synchrony in

competitive settings have been found to be high (Tschacher et al. 2014), Cohen's f^2 = was set at .35, representing a high effect size (Cohen 1988). This was also in accordance with the R^2 we found in our analyses (see "Results"). The α-level was set at .05 and the "Number of tested predictors" at 2. Sample size was set at $N = 39$. The calculation resulted in a power of .90.

Results

Sample Characteristics

The average age was 22.81 ($SD = 3.36$) and participants were predominantly highly educated; The majority ($n = 74$, 92.5%) had at least completed university entrance-level qualifications, five individuals (6.3%) had completed secondary school, and one individual (1.3%) had completed elementary school.

Surrogate Analyses

On average, participants debated for 6.09 min ($SD = 2.51$; *range* 2.30–10) before they continued with small talk. To evaluate nonverbal synchrony, so-called "pseudointeractions" were applied (Bernieri et al. 1988). That is, the genuine nonverbal synchrony values can be compared to cross-correlations that might be expected by chance. We followed the instructions from Ramseyer and Tschacher (2010) to generate the pseudointeractions: Surrogate datasets were produced by shuffling the mentioned 60-s-segments within the time series of both dyad members, and then computing a distribution of pseudosynchronies. This segment-wise approach keeps the structure of the original movement intact, which enables a more realistic and conservative comparison of genuine nonverbal synchrony with pseudosynchronies. On the basis of each dyad's distribution of pseudosynchronies, an effect size was estimated for the present sample. The effect size was computed as follows: mean synchrony minus mean pseudosynchrony divided by *SD* of pseudosynchronies, which is analogous to Cohen's *d*. The result was $d = 1.33$ for the debate-only time series and $d = 1.41$ for the truncated time series, indicating that nonverbal synchrony was present above chance level, with a large effect size.

A similar concern arises within the complementarity measures, as "cross correlations can be spurious, reflecting only the autocorrelations within each time series, rather than any real connection between the series" (Sadler et al. 2009, p. 1010). Accordingly, to address the concern of autocorrelations, we generated 1000 pseudointeractions for dominance and 1000 pseudointeractions for affiliation by randomly pairing time series of participants who did not interact with each other (Gurtman 2001; Markey et al. 2010; Sadler et al. 2009). We performed a Welch two-sample *t* test on the average complementarity values for the genuine dyads ($M_{\text{dominance}} = .41$, $SD = .24$; $M_{\text{affiliation}} = .47$, $SD = .16$) and pseudointeractions ($M_{\text{dominance}} = .01$, $SD = .01$; $M_{\text{affiliation}} = .00$, $SD = .09$). The average complementarity for the observed dyads was reliably higher than the average complementarity for the pseudointeractions: $t_{\text{dominance}}$ (38.50) = 10.47, $p < .001$, Cohen's $d = -3.77$; $t_{\text{affiliation}}$ (38.83) = 18.03, $p < .001$, Cohen's $d = 5.27$. Hence, as can also be seen from Fig. 3, the cross-correlations between dyad members was not a result of autocorrelation.

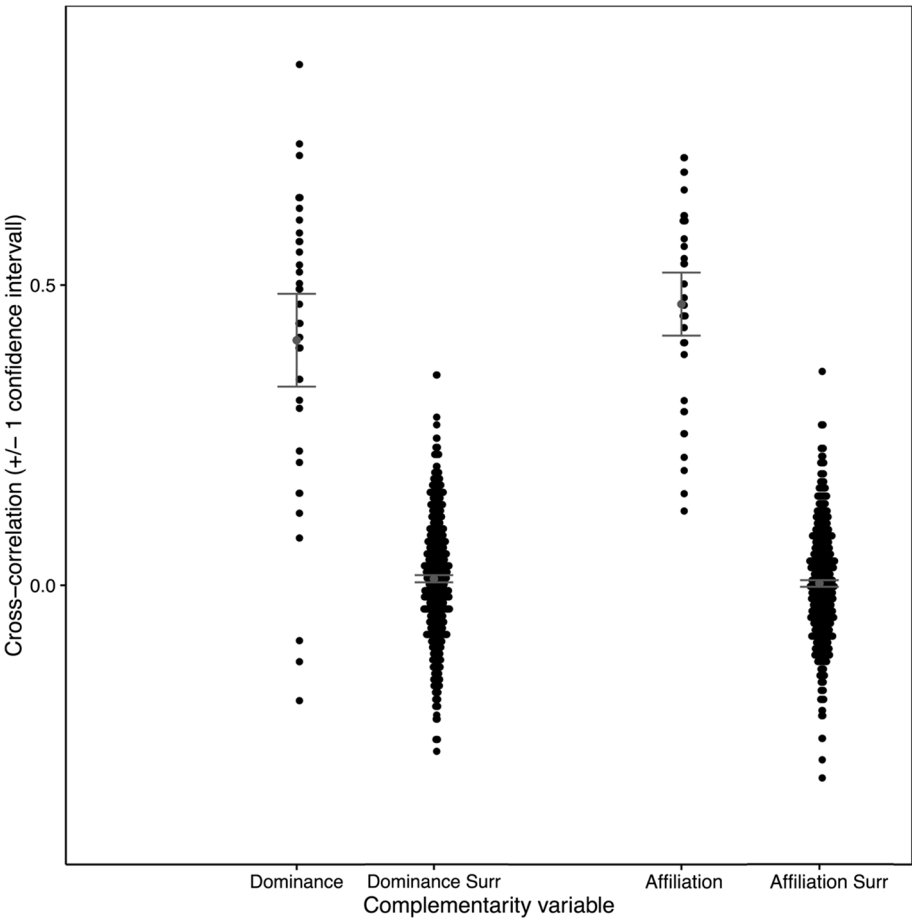

Fig. 3 Complementarity (indexed by cross-correlations) along the dimensions dominance and affiliation for the genuine sample ($N = 39$) grouped together with pseudointeractions ("Surr"; $n = 1000$). Note that cross-correlations for the dimension dominance were multiplied by − 1

Comparison of Nonverbal Synchrony and Complementarity

Robust regression analysis was conducted to examine whether complementarity predicted nonverbal synchrony. The regression model for the measures restricted to debate and the model for the overall measures included dominance and affiliation complementarity as predictors and nonverbal synchrony as dependent variable. In line with our hypothesis, complementarity measures restricted to debate were associated with nonverbal synchrony restricted to debate, but only for the dimension of affiliation, $B = .10$, $SE = .03$, $p < .01$, $F(2, 36) = 6.76$, $p < .01$, model $R^2 = .23$. This means that dyads that showed complementary affiliation behavior during the debate also showed higher nonverbal synchrony. In this model, however, nonverbal synchrony restricted to debate was not associated with dominance complementarity restricted to the debate ($B = -.02$, $SE = .03$, $p = .39$).

With regard to overall measures, affiliation complementarity was associated with overall nonverbal synchrony as a trend, $B = .05$, $SE = .03$, $p = .08$, $F(2, 36) = 1.61$,

$p = .21$, model $R^2 = .03$. Moreover, dominance ($B = .0002$, $SE = .02$, $p = .99$) was not associated with nonverbal synchrony (see also Table 1 for correlative values).

Task Characteristics, Nonverbal Synchrony, and Complementarity

With regard to task outcome, 7 dyads (17.95%) agreed to share the car, 21 dyads (53.85%) agreed that one individual would obtain the car, and 11 (28.21%) dyads did not reach an agreement. Analyses with Kruskal–Wallis nonparametric tests were conducted to examine whether nonverbal synchrony, affiliation complementarity, and dominance complementarity predicted task outcome. However, regarding these measures restricted to the debate, neither nonverbal synchrony, $H(2) = .39$, $p = .82$, nor the complementarity measures, dominance: $H(2) = .13$, $p = .93$; affiliation: $H(2) = 2.11$, $p = .35$, did vary significantly with respect to task outcome. Furthermore, these measures were also non-significant with regard to the complete role-play [nonverbal synchrony: $H(2) = .91$, $p = .63$; dominance: $H(2) = 3.99$, $p = .14$; affiliation: $H(2) = .84$, $p = .66$].

A robust regression analysis was conducted to examine whether complementarity and nonverbal synchrony predicted the duration of the debate (in seconds). The regression model for the measures restricted to debate and the model for the overall measures included nonverbal synchrony, dominance and affiliation complementarity as predictors and duration as dependent variable. With regard to complementarity restricted to the debate, the dimension of affiliation negatively predicted duration of the debate, $B = -373.3$, $SE = 158.8$, $p < .05$, $F(3, 35) = 2.14$, $p = .11$, model $R^2 = .08$, whereas the dimension of dominance ($B = 137.9$, $SE = 130.3$, $p = .30$) and nonverbal synchrony ($B = 742.9$, $SE = 829.6$, $p = .38$) did not. This means that dyads with higher affiliation complementarity debated for a shorter time period.

This association was reinforced in a further model with regard to overall affiliation complementarity and duration, $B = -328.44$, $SE = 144.86$, $p < .05$, $F(3, 35) = 4.86$, $p < .01$, model $R^2 = .23$. Moreover, in the same model, overall dominance complementarity was positively correlated with duration ($B = 252.47$, $SE = 94.34$, $p < .05$). That is, dyads with higher overall dominance complementarity took longer to come to an agreement. By contrast, in the same model, nonverbal synchrony was not associated with duration ($B = 1150.44$, $SE = 911.66$, $p = .22$).

Additionally, we tested for sex-specific differences in nonverbal synchrony and complementarity. However, we found no sex differences regarding nonverbal synchrony, $M_{\text{female}} = .14$, $SD = .03$; $M_{\text{male}} = .13$, $SD = .02$; $t(37.00) = 1.24$, $p = .22$, Cohen's $d = .40$, or nonverbal synchrony restricted to debate, $M_{\text{female}} = .15$, $SD = .04$; $M_{\text{male}} = .14$, $SD = .03$; $t(34.78) = 1.25$, $p = .22$, Cohen's $d = .40$. Similarly, no sex differences were found for affiliation complementarity, $M_{\text{female}} = .49$, $SD = .16$; $M_{\text{male}} = .44$, $SD = .17$; $t(36.61) = .89$, $p = .38$, Cohen's $d = .28$, affiliation complementarity restricted to debate, $M_{\text{female}} = .49$, $SD = .17$; $M_{\text{male}} = .41$, $SD = .18$; $t(36.40) = 1.44$, $p = .16$, Cohen's $d = .46$, dominance complementarity, $M_{\text{female}} = .40$, $SD = .21$; $M_{\text{male}} = .42$, $SD = .24$; $t(37) = -.22$, $p = .83$, Cohen's $d = .07$, or dominance complementarity restricted to debate, $M_{\text{female}} = .44$, $SD = .17$; $M_{\text{male}} = .56$, $SD = .18$; $t(36.7) = -.77$, $p = .45$, Cohen's $d = .24$.

Table 1 Pairwise correlation matrix

	Dom	Aff	Sync	Dom (deb)	Aff (deb)
Aff	− .02				
Sync	.01	.29†			
Dom (deb)	.74***	− .02	.007		
Aff (deb)	.02	.89***	.39*	.08	
Sync (deb)	− .06	.39*	.80***	− .10	.50**

All correlations are based on a degree of freedom $N_{dyads} - 2 = 37$. *Aff* Affiliation complementarity, *Dom* dominance complementarity (multiplied by − 1), *deb* measures restricted to the debate, *Sync* nonverbal synchrony

*$p < .05$; **$p < .01$; ***$p < .001$; $^{\dagger}p < .10$

Discussion

In the current study, the phenomenon of being on the same "wavelength", and its outcomes during a competitive setting, were explored by nonverbal synchrony based on motion energy analysis (MEA) and complementarity based on a joystick tracking method. While the former method continuously captured an individual's overall body movement, the latter assessed verbal and nonverbal affiliation and dominance behavior during the time observed. With regard to MEA, the surrogate analysis of the present study demonstrated that individuals significantly synchronized their movement during a competitive debate. Notably, the effect size in the present sample (Cohen's $d = 1.33$) was higher than the medium to high effect sizes reported in previous research utilizing MEA in a competitive context ($d = .76$ in Tschacher et al. 2014). This finding suggests, as previously reported by Tschacher et al. (2014), that nonverbal synchrony depends on task instructions and is particularly high in competitive settings.

The present findings from the joystick tracking method were consistent with the predictions of complementarity. That is, affiliation in one dyad member corresponded with affiliation in the other, whereas dominance evoked submission. Surrogate analyses revealed large effect sizes for complementarity ($d \geq 3.77$). However, since cross-correlations were computed differently for nonverbal synchrony and complementarity, effect sizes from the two methods cannot be compared (Ramseyer and Tschacher 2010). Nevertheless, in line with previous research (e.g., Kupper et al. 2015; Thomas et al. 2014), both findings suggest that nonverbal synchrony and complementarity were not a result of statistical artifacts.

The current findings were partly in line with our hypothesis that complementarity is positively associated with nonverbal synchrony. In terms of affiliation, our findings are in accordance with results from studies providing evidence of a positive relationship between affiliation and synchronized motor activity or behavioral mimicry (Farley 2014; Hove and Risen 2009; Lakin and Chartrand 2003). Dominance complementarity was not related to nonverbal synchrony. One explanation for this might be that dominance complementarity affected the perception of hierarchy within the dyad (Tiedens and Fragale 2003). Accordingly, Tiedens and Fragale (2003) observed that when male and female participants interacted with a dominant confederate, their own body postural stance (amount of space a participant filled, e.g., by moving one's limbs from the body) decreased, whereas when they interacted with a submissive confederate, their body postural stance increased. With

regard to the present findings, it may be speculated that dominance complementarity was represented by dominant gestures in one individual (high amount of movement) and submissive gestures in the other individual (low amount of movement; see also Vicaria and Dickens 2016).

In the current examination, the duration of the debate was negatively related to affiliation complementarity. This finding is in line with previous research (Estroff and Nowicki 1992; Markey et al. 2010), which found that dyads who altered their affiliation-related behavior in a complementary manner showed a quicker task performance. Surprisingly, we also found a positive relationship between the duration of the debate and dominance complementarity. However, this relationship was not present for dominance complementarity restricted to the debate. It is possible that affiliation complementarity may have contributed to a favorable interaction, and therefore a shorter duration of the debate. Dominance complementarity, in turn, might have contributed to a more explicit distribution of hierarchical roles ("winner and loser"), which persisted or even increased during the complete interaction. However, these results have to be interpreted with caution, as the type of interaction has been shown to be a moderator of complementarity (Moskowitz et al. 2007) and its relationship to task outcome (Halevy et al. 2011; Nowicki et al. 1997). Although the duration of the debate was significantly longer in the group with no agreement than in the group in which one individual obtained the car, complementarity measures and nonverbal synchrony did not differ with respect to task outcome groups. Possibly, a competition with more substantial consequences for the participants (e.g., financial incentive) would have led to different results.

Furthermore, the null results with regard to nonverbal synchrony and debate duration may be due to the fact that the function of nonverbal synchrony in goal-oriented behavior is still not fully understood. Indeed, the *more means better hypothesis* (stronger synchronization leads to better task performance; see also Richardson and Dale 2005) has recently been challenged. Specifically, Abney et al. (2015) demonstrated that loosely synchronized, or in other words more flexibly adapting dyads, performed better in a cooperative task. Moreover, Boker (2004) proposed an inverted U-shaped relationship between nonverbal synchrony and relationship quality, with too much synchronization ("mime effect") negatively affecting relationship quality.

The results of the present study make several important contributions to the literature on the phenomenon of synchronization. To the best of our knowledge, this study is among the first not only to compare interpersonal complementarity with movement synchrony but also to examine its correlates with competitive behavior. The present study also provides a conceptual comparison of two distinct theories, namely interpersonal theory and embodiment, which both underline the importance of the social context when examining cognition, emotion, and behavior. That is, both theories make predictions about synchronization processes within a dyad, but differ in their operationalization (i.e., complementarity vs. nonverbal synchrony). For instance, whereas movement is the central dependent variable within the research of nonverbal synchrony, complementarity also captures verbal behavior and qualitative aspects (dominance vs. affiliation) in social functioning.

However, several limitations have to be emphasized with regard to the current findings. First, the cross-correlations (complementarity) and the segment-wise cross-correlations (nonverbal synchrony) represent highly aggregated measures. Therefore, these measures are mostly global and do not provide information on the progression of synchronization over time within the dyads. Additionally, the nonverbal synchrony measures restricted to the debate have to be interpreted with caution, as the segment-wise computation provides

less reliable results when the duration of time series decreases. However, cross-correlations represent an intuitive and appropriate overall index, which has frequently been applied in the context of interactional research (Sadler et al. 2009). Second, the present results have to be interpreted against the background of the constraints of the specific laboratory setting, including a competitive setting with a specific role-play and a relatively small number of unacquainted same-sex dyads. Hence, different results may be obtained depending on the context and interpersonal behaviors being investigated. Moreover, some of non-significant findings could be due to the lack of power (e.g., non-significant sex differences in synchronization). Importantly, since we did not conduct a manipulation check, it cannot be ruled out that the role-play failed to induce competitiveness.

Further experimental research could examine the influence of acute stress on the phenomenon of synchronization by comparing stressed dyads with control dyads, in contrast to the present procedure, in which one participant in each dyad was stressed. Additionally, future studies should compare competitive with non-competitive tasks and examine alternative competitive contexts with "real" consequences for the individuals (e.g., financial incentive). To investigate the effects of personality, further statistical approaches could use Actor-Partner-Interdependence Models (Kenny and Ledermann 2010). Notably, the exploratory results reported in "Appendix" section further indicate that complementarity in dominance and affiliation is linked to pain related behavior. Therefore, future research may include topics such as pain avoidance or empathy (see also Flor et al. 1995; Hurter et al. 2014) and link them to dyadic behavior.

Conclusion

The present results provide first evidence that dyads that complement each other with regard to affiliation also show higher nonverbal synchrony. However, the association between dominance complementarity and nonverbal synchrony was not significant. Above all, our results reinforce the view that competitive behavior depends on complex dyadic interactions, including nonverbal and verbal behavior. We offer a preliminary insight into the role of two aspects of synchronization in a specific competitive context. The processes of interpersonal coordination as well as their disturbances might further be investigated in contexts such as clinician-patient or intra-team interactions.

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Appendix: Methodological Description and Dyad-Level Correlations of an Adapted Version of the Cold Pressor Test

To assess additional dyadic competitive behavior, an adapted version of the Cold Pressor Test (CPT; Hines and Brown 1936) including social evaluation (Schwabe et al. 2008) and implicit competition was conducted. In contrast to other previously applied versions of the CPT task (e.g., Ferreira-Valente et al. 2011; Roberts et al. 2015), our version required both participants to simultaneously immerse their right hand in ice water (temperature was 4 °C) while being seated in chairs opposite to and facing each other. In this way, we

Table 2 Dyad-level correlations

	Dom	Aff	Sync	Dom (deb)	Aff (deb)	Sync (deb)	CPT PT	CPT PR
CPT PT	− .004	− .39*	− .04	.16	− .44*	− .19	**.62*** **	
CPT PR	.12	.49*	.28	− .08	.52*	.26	− .62**	**.42*** **

Aff affiliation complementarity, *CPT* cold pressor test, *Dom* dominance complementarity (multiplied by − 1), *deb* measures restricted to the debate, *PR* pain rating, *PT* pain tolerance, *Sync* nonverbal synchrony. Intraclass correlations are in boldface. Dyad-level correlations and tests of significance are based on $N = 39$ ($df = 37$) and the formula provided by Griffin and Gonzalez (1995)

*$p < .05$; **$p < .01$; ***$p < .001$

intended to increase the task's competitive character. They were told to keep their hand up to and including the wrist in the ice water for as long as possible. To increase the competitive nature of the test, both dyad members put their hands into the same container and the examiners stayed in the room observing and timing them. This procedure is comparable to studies applying social evaluative cold pressor tests, which are conducted in groups (Minkley et al. 2014) or with the presence of examiners (Schwabe et al. 2008). The examiners announced the immersion time and stopped the task after 3 min, but participants were told that it was their own decision to remove their hand before. Immediately after drying their hand, participants completed a one-item visual analogue scale (0 *least* to 10 *most painful*) to rate how painful this adapted version of the CPT was (Ferreira-Valente et al. 2011).

Since all dyads were same sex pairs and assignment to be either dyad member 1 or 2 was random, dyads were treated as exchangeable or indistinguishable (Kenny and Cook 1999). For this case, Griffin and Gonzalez (1995) provide a method for calculating dyad-level correlations based upon the intraclass correlation including a sample size correction. Accordingly, dyad-level correlations were performed for the CPT, nonverbal synchrony and complementarity measures.

On average, with regard to pain tolerance (PT), participants kept their hand in the water for 127.54 s ($SD = 65.81$; *range* 10–180). An average pain rating (PR) of 5.85 ($SD = 2.19$; *range* .73–9.17) was reported. The correlations of interest are presented in Table 2.

As can be concluded from the intraclass correlations, dyad members were similar on the measures PT ($r = .62$, $p < .001$) and PR ($r = .42$, $p < .001$). Moreover, the dyad-level correlation between PT and PR was significantly negative ($r = - .62$, $p < .01$). This indicates that dyads in which both members showed a high PT are also dyads in which both members showed low PR. With regard to our exploratory hypotheses, we found a positive relationship between affiliation complementarity and the PR ($r_{\text{overall}} = .49$, $p < .05$; $r_{\text{restricted to debate}} = .52$, $p < .05$). This indicates that dyads in which both members showed high PRs are also dyads in which both members showed a higher affiliation complementarity. These findings were supported by the PT measures ($r_{\text{overall}} = - .39$, $p < .05$; $r_{\text{restricted to debate}} = - .44$, $p < .05$), indicating that dyads in which both members showed low PTs are also dyads in which both members showed a higher affiliation complementarity.

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