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Fast track report

Too late to coordinate: Contextual influences on behavioral synchrony

LYNDEN K. MILES[1]*, JORDAN L. GRIFFITHS[1],
MICHAEL J. RICHARDSON[2] AND C. NEIL MACRAE[1]
[1]*University of Aberdeen, UK*
[2]*University of Cincinnati and Colby College, USA*

Abstract

The temporal coupling of behavior serves as a foundation for effective social exchange with synchronized actions moderating core components of social-cognitive functioning. Questions remain, however, regarding the precise conditions under which this form of behavioral coordination emerges. In particular, do social factors moderate the extent to which people synchronize their movements with others? Given that synchrony serves as an important non-verbal route through which interpersonal connections can be forged, the current investigation considered whether contextual influences moderate the emergence of behavioral coupling. To explore this issue, movements were recorded while participants performed a repetitive activity (i.e., stepping) with an interaction partner who either turned up for the experiment on time or was 15 minutes late. Results revealed that coordination (i.e., in-phase synchrony) was substantially reduced when participants interacted with a tardy partner, a finding that highlights the impact that social factors exert on the spontaneous emergence of behavioral synchrony. Copyright © 2009 John Wiley & Sons, Ltd.

An intriguing facet of daily life is that people spontaneously coordinate their behaviors with those of an interaction partner (e.g., Bernieri & Rosenthal, 1991; Cappella, 1997; Chartrand & Bargh, 1999; Chartrand, Maddux, & Lakin, 2005; Marsh, Richardson, & Schmidt, 2009; Wilson & Wilson, 2005). As Chartrand et al. (2005, p. 335) have observed, "You smile, I smile. You rub your chin—darned if my hand does not gravitate toward my chin as well." Imitation has been ascribed several important interpersonal functions (Lakin, Jefferis, Cheng, & Chartrand, 2003). Individuals mimic those they like (Chartrand & Bargh, 1999) or wish to affiliate with (Lakin & Chartrand, 2003; Lakin, Chartrand, & Arkin, 2008), but refrain from imitating disliked others (Stel, Blascovich, McCall, Mastop, van Baaren, & Vonk, in press) or members of unpopular out-groups (Bourgeois & Hess, 2008; Yabar, Johnston, Miles, & Peace, 2006), suggesting that coordination may represent a means to regulate interpersonal relationships.

Compelling though imitative episodes may be, behavioral coupling can manifest an arguably yet more impressive quality—temporal alignment. Importantly, the matching of behavior in both form and time (i.e., interpersonal synchrony) has also been posited as a pathway through which people can influence their connections with others (Marsh et al., 2009; Semin, 2007; Semin & Cacioppo, 2008). In particular, synchrony elicits feelings of connectedness and rapport and enhances the memorability of a dyadic interaction (e.g., Bernieri & Rosenthal, 1991; Hove & Risen, in press; LaFrance, 1979; Macrae, Duffy, Miles, & Lawrence, 2008; Miles, Nind, & Macrae, 2009; Wiltermuth & Heath, 2009). Notwithstanding the demonstration of these effects however, little is known about the wider interpersonal factors that moderate this form of coordination—for example, are there social contexts in which the emergence of interpersonal synchrony is inhibited or disrupted?

*Correspondence to: Lynden K. Miles, School of Psychology, University of Aberdeen, King's College, Aberdeen AB24 3FX, Scotland, UK.
E-mail: lynden.miles@abdn.ac.uk

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Alongside various neural and representational mechanisms that have been proposed to subserve the spontaneous emergence of interpersonal coordination (e.g., Iacoboni, 2009; Rizzolati & Craighero, 2004; Prinz, 1997; Tognoli, Largarde, DeGuzman, & Kelso, 2007; Wilson, 2001; Wilson & Knoblich, 2005), a complementary explanation lies in an understanding of the self-organized dynamics that govern the actual behaviors themselves (see Strogatz, 2003). Just as the synchronized activity of clusters of cardiac pacemaker cells or gatherings of fireflies is understood to result from the self-organizing processes of a coupled oscillator dynamic, so too is interpersonal coordination (Haken, Kelso, & Bunz, 1985; Kelso, 1995; Kugler & Turvey, 1987; Schmidt & Richardson, 2008). Central to this viewpoint is the observation that in-phase and anti-phase synchrony represent the stable modes of coordinated action both mathematically (Haken et al., 1985) and empirically (see Schmidt & Richardson, 2008 for an overview). These patterns of movement pertain to a wide range of activities, including walking, limb movements, the swinging of handheld pendulums, and the motion of rocking chairs (Richardson, Marsh, Isenhower, Goodman, & Schmidt, 2007; Richardson, Marsh, & Schmidt, 2005; Schmidt, Carello, & Turvey, 1990; van Ulzen, Lamoth, Daffertshoer, Semin, & Beek, 2008). Moreover, recent research indicates that the mode of coordination has important social-cognitive implications. Specifically, stable modes of synchrony are associated with higher ratings of rapport (Miles et al., 2009) and liking (Hove & Risen, in press), and facilitate memory for an interaction partner (Macrae et al. 2008) compared to less stable forms of coordination.

Given the ubiquity of behavioral synchrony (Semin, 2007; Semin & Cacioppo, 2008), important questions arise regarding the boundary conditions of this phenomenon. Notable among these is the issue of whether there are particular circumstances under which people are more or less likely to coordinate their actions with others? Consider, for example, a situation in which two individuals are swinging hand-held pendulums (e.g., Schmidt & O'Brien, 1997)—would the emergence of synchrony be influenced by social factors, such as whether the interacting individuals had just traded insults or compliments? It may be tempting to presume that the self-organizing systems that sustain interpersonal coordination are not vulnerable to the influence of higher order factors such as social goals and motives. After all, these systems are firmly grounded in physics (Strogatz, 2003), hence may be impenetrable to social-cognitive forces. On the other hand however, dynamical, self-organized processes have been shown to underlie a range of complex emotional, developmental and social psychological phenomena (see Lewis & Granic, 2000; Vallacher & Nowak, 1994). For example, fluctuations in the degree of synchronized clapping among the members of an audience are self-organized with respect to their desire to express appreciation (Néda, Ravasz, Brechet, Vicsek, & Barabási, 2000), while Schmidt, Christianson, Carello, and Baron (1994) have reported that individual differences in social competence impact the characteristics of synchrony within a dyad. What these studies suggest is that the coordination dynamics that underlie interpersonal synchrony may be sensitive to the operation of overarching social goals. We explored this possibility in the current inquiry.

Prior to performing a repetitive activity (i.e., stepping) with an interaction partner (in reality an experimental confederate), we created a task context in which some participants had reason to view their interaction partner in a negative fashion such that the formation of interpersonal rapport might be disrupted. Specifically, while for some participants the confederate turned up for the experimental session exactly on time, for others she was 15 minutes late thereby requiring participants to wait, unoccupied, for this period. Previous research using this manipulation has shown that being delayed in this manner prompts negative feelings (Atkinson & Polivy, 1976; Butcher & Heffernan, 2006; Taylor, 1994) and anti-social behavior (Holmes, 1972) toward the source of the delay. Together, these effects may potentially serve to reduce participants' proclivity to establish rapport with the tardy individual. In this respect, behavioral coordination—as means to develop or inhibit interpersonal connections (Semin, 2007)—may serve as a subtle, but critical, medium through which people can influence the extent to which they affiliate with interaction partners. As such, we expected that differences in the social context resulting from the confederate's punctuality or tardiness would influence the emergence of interpersonal synchrony during the stepping task.

METHOD

Participants and Design

Twenty-six female undergraduates took part in the research in exchange for course credit. The experiment had a single-factor (Confederate: On-time vs. Late) between-participants design. The study was reviewed and approved by the School of Psychology, University of Aberdeen Ethics Committee.

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Procedure

Participants arrived at the laboratory individually and were informed that the study was concerned with interpersonal interactions and, therefore, required two individuals to take part. Importantly, the supposed other participant was in fact a female confederate to the experiment who was either already present when the participant arrived, or appeared 15 minutes after the participant. When the confederate arrived late, she gave no explanation or apology for her tardiness.[1] The experimenter then explained that prior to taking part in the social interaction task, a short period of light physical activity was necessary to ensure adequate levels of physiological arousal.

Prior to the physical activity, both the participant and confederate (in order to maintain the cover-story) were also asked to complete two brief questionnaires. First they completed a shortened version of a standard rapport questionnaire (Bernieri, Davis, Rosenthal, & Knee, 1994). They were asked to indicate, on a nine-point scale (anchored by: 0 = not at all; 8 = extremely), the degree to which each item described their expectations of the interaction. Five items assessed positive aspects of rapport (*comfortable*, *friendly*, *harmonious*, *positive*, *satisfying*) and five items assessed negative aspects of rapport (*awkward*, *boring*, *cold*, *dull*, *slow*). They then completed a shortened version of the Positive and Negative Affect Scale (PANAS; Watson, Clark, & Tellegen, 1988) by indicating on a nine-point scale (anchored by: 0 = not at all; 8 = extremely), the degree to which each item described the way they felt at that moment. Ten items assessed positive affect (*determined*, *energetic*, *cheerful*, *sociable*, *motivated*, *enthusiastic*, *independent*, *attentive*, *alert*, *excited*) and ten items assessed negative affect (*irritated*, *disgusted*, *hostile*, *lazy*, *tired*, *lonely*, *angry*, *downhearted*, *alone*, *sad*).

The physical activity consisted of 90 seconds of stepping on a standard exercise step (riser height 15 cm). The stepping movements of both the participant and the confederate were recorded at 120 Hz using a magnetic motion tracking system (Polhemus Liberty, Polhemus Corporation, Colchester, VT) with sensors attached to the lateral part of each leg above the knee. The exercise steps were arranged adjacent to one another with the confederate's step 50 cm in front of the participant's (see Figure 1). Both the confederate and the participant wore headphones with white noise being played to the participant and metronome tones (84 bpm[2]) to the confederate. During the activity, the confederate stepped in time with the metronome tones. For the initial 30 seconds of the trial the participant stepped alone, allegedly as a means to calibrate the equipment. This served as the "baseline" stage of the procedure and was included to measure chance coordination. Following this stage the confederate and the participant stepped together. This served as the "test" stage of the procedure and lasted for 60 seconds.

Upon completion of the stepping task, participants were funnel debriefed with respect to any suspicions they had about the study or the confederate's role. All participants reported that they thought the confederate was in fact another participant and none reported any suspicions about the study. Participants were then fully debriefed and dismissed.

Data Reduction

Prior to analysis, each time series of movement data was centered around 0 and low-pass filtered using a 10 Hz Butterworth filter. The relative phase relationship between the participant's and confederate's leg movements (in the vertical plane) was calculated separately for left-left and right-right leg comparisons and the results averaged. Relative phase was normalized to a range of 0°–180° and the distribution of relative phase angles across nine 20° regions of relative phase (0°–20°, 21°–40°...161°–180°) were determined by calculating the frequency of coordination occurring within each of these regions (Schmidt & O'Brien, 1997). Baseline (i.e., chance) coordination was calculated by comparing participant movements during the 30 seconds period when they stepped alone, with the confederate's movements during the first 30 seconds of the test stage of the procedure. Thus, for each participant, raw movement data (relative to the confederate) was reduced to estimates of the time spent in each of the nine relative phase regions for the baseline and test stages separately. Coordination is indicated by a concentration of relative phase angles in the portions of the distribution near 0° (i.e., in-phase coordination) and/or 180° (i.e., anti-phase coordination).

[1]Apologies moderate negative feelings resulting from a delay (Butcher & Heffernan, 2006) as do attributions for the cause of the delay to external or uncontrollable factors (Taylor, 1994; Tom & Lucey, 1995).
[2]Pilot testing ($n = 5$) using the same exercise step revealed that on average individuals spontaneously stepped at approximately this frequency and were able to maintain it comfortably for at least 2 minutes.

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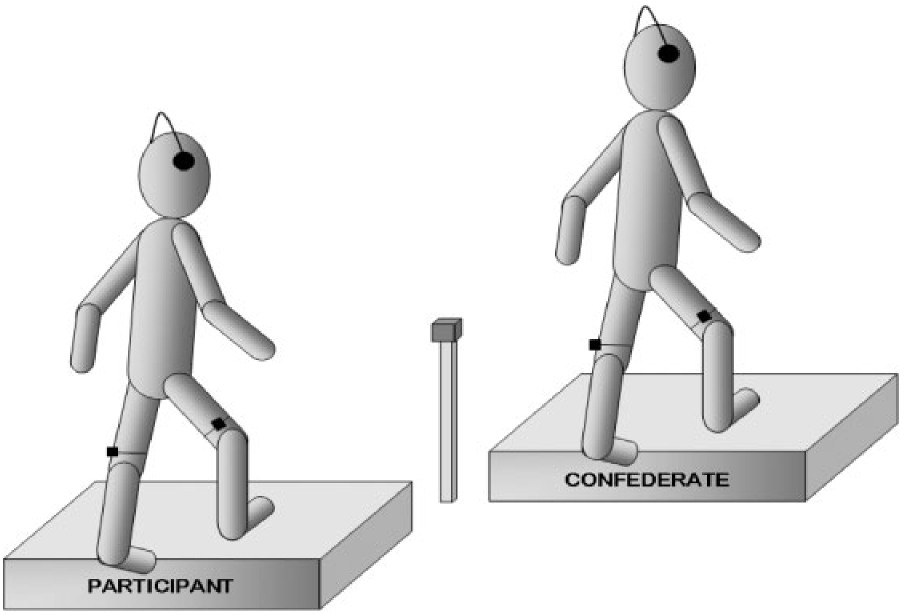

Figure 1. Diagram of the experimental set-up. The confederate's step was placed 50 cm in front of the participant's in order to ensure the confederate was comfortably within the participant's field of view, but that the confederate could not see the participant. The source of the magnetic field used for motion tracking was located mid-way between the participant and confederate

RESULTS

Synchrony

The relative phase relationship[3] between participant and confederate leg movements was compared using a 2 (Condition: On-time or Late) × 2 (Stage: Baseline or Test) × 9 (Relative Phase Region: 0°–20°, 21°–40°...161°–180°) mixed model analysis of variance (ANOVA) with repeated measures on the final two factors. Main effects of Stage [$F(1, 24) = 8.18$, $p < .005$, $\eta_p^2 = 0.25$] and Phase Region [$F(8, 192) = 14.42$, $p < .001$, $\eta_p^2 = 0.38$] were qualified by 2-way interactions between Condition × Phase Region [$F(8, 192) = 3.44$, $p < .005$, $\eta_p^2 = 0.13$] and Stage × Phase Region [$F(8, 192) = 10.19$, $p < .001$, $\eta_p^2 = 0.31$] and, importantly, a 3-way Condition × Stage × Phase Region interaction [$F(8, 192) = 2.95$, $p < .005$, $\eta_p^2 = 0.11$]. Inspection of Figure 2 indicates an increased concentration of relative phase angles in the 0°–20° region (i.e., in-phase coordination) during the test stage. Post hoc tests (Tukey *a*) revealed that this was indeed the case for participants in the on-time condition. That is, their footsteps were coordinated, in an in-phase mode, with those of the confederate at a significantly greater level than during the baseline (i.e., chance) stage ($M_{\text{baseline}} = 13.9\%$, $M_{\text{test}} = 51.2\%$, $p < .001$). However, for participants in the late condition, although there was an elevated level of in-phase coordination during the test stage, this was not significantly different from the baseline ($M_{\text{baseline}} = 12.1\%$, $M_{\text{test}} = 24.5\%$, $p = .45$). Critically, there was also a significant difference in the amount of in-phase coordination exhibited during the test stage by participants in the on-time condition compared to those in the late condition ($p < .001$).

To further investigate the nature of this effect, the test stage interaction period was divided into four 15 seconds epochs and the frequency of coordination in the 0°–20° relative phase region (i.e., in-phase) was compared using a 2 (Condition: On-time or Late) × 4 (Epoch: 1–15 seconds/16–30 seconds/31–45 seconds/46–60 seconds) mixed model ANOVA with repeated measures on the second factor. Only a main effect of condition was revealed [$F(1, 24) = 4.15$, $p < .05$, $\eta_p^2 = 0.15$],

[3]Specifically, the percentage of the interaction where relative phase was within each of the nine 20° relative phase regions. See Pikovsky, Rosenblum and Kurths (2001) for details on the calculation of relative phase, and Richardson et al. (2005) and Schmidt and O'Brien (1997) for more detailed accounts on the application of relative phase to quantifying interpersonal co-ordination.

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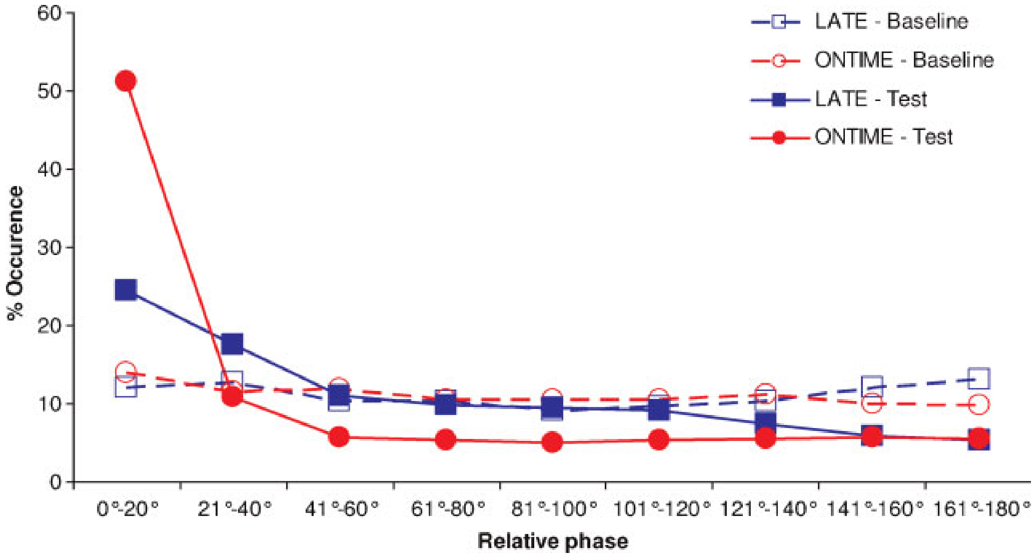

Figure 2. Distribution of the relative phase relationship between participant and confederate leg movements during baseline and test stages as a function of condition (i.e., confederate on-time vs. late)

indicating that the difference in coordination between participants in the on-time and late conditions was consistent across the duration of the 60 seconds interaction period.

Rapport

Indices of mean ratings of rapport were calculated for positive (Cronbach's $\alpha = .94$) and negative (Cronbach's $\alpha = .84$) items separately[4] and compared using a 2 (Condition: On-time or Late) $\times$ 2 (Valence: Positive or Negative) mixed model ANOVA with repeated measures on the second factor. This revealed a main effect of Valence [$F(1, 24) = 62.34$, $p < .001$, $\eta_p^2 = 0.72$] which was qualified by a Condition $\times$ Valence interaction [$F(1, 24) = 4.45$, $p < .05$, $\eta_p^2 = 0.16$]. Post hoc tests (Tukey *a*) indicated that ratings on the positive rapport index were higher for participants in the on-time condition than those in the late condition ($M_{\text{on-time}} = 5.1$, $M_{\text{late}} = 4.0$, $p < .01$) but no such difference emerged for the index of negative rapport items ($M_{\text{on-time}} = 1.7$, $M_{\text{late}} = 2.0$, $p = .90$). In addition, the relationship between ratings of rapport and the frequency of in-phase coordination was considered across the entire sample. Interestingly, higher ratings on the positive rapport index were accompanied by a greater degree of coordination [$r(26) = .37$, $p = .06$] while higher ratings on the negative rapport index were accompanied by lower levels of coordination [$r(26) = -.55$, $p < .01$].

Mood

Indices of mean ratings of mood were calculated for positive (Cronbach's $\alpha = .91$) and negative (Cronbach's $\alpha = .89$) items separately[5] and compared using a 2 (Condition: On-time or Late) $\times$ 2 (Valence: Positive or Negative) mixed model ANOVA with repeated measures on the second factor. This revealed a main effect of Valence [$F(1, 24) = 87.64$, $p < .001$, $\eta_p^2 = 0.79$], indicating that participants furnished higher positive ($M = 4.5$) than negative mood ratings ($M = 1.1$). No other

[4]There was no systematic relationship between participants' ratings of the positive and negative rapport items hence separate indices were calculated according to item valence.
[5]There was no systematic relationship between participants' ratings of the positive and negative mood items hence separate indices were calculated according to item valence.

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significant effects emerged (Fs < 1). Furthermore, there were no significant relationships between ratings of either positive or negative mood and the frequency of in-phase coordination.

DISCUSSION

In the current research, we explored whether the dynamical systems that support the spontaneous emergence of interpersonal synchrony are influenced by the social context within which an interaction takes place. To investigate this issue, we created a situation whereby half of the participants were made to wait, unoccupied, for 15 minutes, while the other half of the participants endured no such delay. Subsequently, all participants stepped repeatedly on an exercise step alongside a confederate. Of interest was the degree to which participants spontaneously synchronized their stepping with the tardy or punctual confederate. The results were revealing. While participants in the on-time condition displayed stable in-phase coordination[6] with the footsteps of the confederate, this was not seen for participants in the late condition who failed to coordinate at levels significantly greater than chance (i.e., baseline). Additionally, this effect was consistent across the duration of the interaction period. These results suggest that not only do contextual factors shape the self-organization of the dynamics that sustain behavioral synchrony, but also that a negative social context can inhibit or indeed eliminate the emergence of this form of coordination.

Consideration of the social and affective influences underlying the current results raises a number of important issues. As expected, a more positive interaction was anticipated by the participants who did not endure the 15 minutes wait compared to those who were delayed by the tardy confederate. Importantly, this difference in perceived rapport was accompanied by a clear distinction with respect to the emergence of behavioral synchrony. When a more positive interaction was anticipated (i.e., in the on-time condition), participants showed stable in-phase synchrony with the actions of the confederate. Conversely, when anticipated interaction quality was lower (i.e., in the late condition) no such synchrony was observed. These findings are consistent with conceptually similar mimicry research which suggests that individuals do not imitate those toward whom they hold negative feelings (e.g., Bourgeois & Hess, 2008; Stel et al., in press; Yabar et al., 2006). Moreover, the general (i.e., irrespective of experimental condition) relationships revealed between anticipated rapport and coordination add further support to the proposed link between stable interpersonal synchrony and positive social outcomes (Hove & Risen, in press; Macrae et al., 2008; Marsh et al., 2009; Miles et al., 2009; Semin & Cacioppo, 2008; Wiltermuth & Heath, 2009). In short, it appears that synchronous actions co-vary with differences in the expected affective tone of a social interaction, suggesting that the presence (or absence) of interpersonal synchrony may act as a medium for forging (or dissuading) social connections.

However, perhaps surprisingly, participants did not report significant differences in mood as a function of experimental condition (i.e., on-time vs. late), nor was mood seen to be related to the emergence of coordination. Although differences in mood have been reported in previous studies that have employed a similar manipulation (e.g., Atkinson & Polivy, 1976; Butcher & Heffernan, 2006; Taylor, 1994) and have been shown to influence non-conscious mimicry (van Baaren, Fockenberg, Holland, Janssen, & van Knippenberg, 2006) the circumstances in which participants were delayed, in combination with the manner in which mood was evaluated may have contributed to the absence of mood effects in the present study. Specifically, participants in the late condition were delayed for 15 minutes within the context of a purportedly 45 minutes study for which they were granted course credit regardless of whether the ‘‘other participant’’ arrived or not. Consequently, the relatively limited duration of the delay and lack of personal consequences for the participant may have limited the impact of the lateness manipulation on mood. Moreover, mood was assessed in a general sense (i.e., how do you feel at the moment) whereas, by comparison, assessments of rapport were targeted with respect to feelings about the confederate, or more specifically the impending interaction with them. In this way the negative influence of being delayed appears to have been limited to judgments regarding the source of the delay (i.e., the confederate) and,

[6]Interestingly, we found no anti-phase coordination (i.e., temporal matching between the actions of the participant's left leg and the confederate's right leg, or *vice versa*). Inspection of data from individual participants indicates evidence of a trend toward anti-phase coordination for at least two participants, but this was not seen when the data were pooled across the entire sample. However, this may not be entirely unexpected as in-phase coordination represents the globally stable attractor state and, consequently, is more frequently observed for interpersonal synchrony due to the relatively weak nature of visual couplings (see Richardson et al., 2007 for further discussion). Moreover, the confederate always began stepping with her right foot which may have been imitated by the participants who showed significant levels of coordination, or simply emerged as a function of the tendency toward right foot dominance within the population (approximately 80%, Gabbard & Iteya, 1996).

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importantly, the subsequent interaction, rather than impacting mood more generally. Nonetheless, given previous work revealing a relationship between mood and mimicry (van Baaren et al., 2006) a more rigorous examination of the influence of this factor on interpersonal synchrony may be warranted.

Although the present results indicate that social context can moderate the dynamics that support interpersonal coordination, broad questions remain as to how exactly this may occur. According to a dynamical systems approach, the same physics that sustain the coordination of, for instance, flashing fireflies also lead to the self-organization of interpersonal coordination (Haken et al., 1985; Schmidt & Richardson, 2008; Strogatz, 2003). Such generality provides substantial explanatory power but also demands clarification when it is seen not to apply, for instance when systematic differences in synchrony are observed as in the current study. One potential explanation rests with the strength of the coupling between individuals. In order for any two oscillators (e.g., flashing fireflies, limbs) to exhibit self-organized coordination they must be coupled in some way (e.g., via biomechanical, visual, or auditory information). In the current study, the participant and confederate were primarily coupled via visual information.[7] In this sense, the participant was able to control the nature of the coupling by means of directing her visual attention toward, or away from, the confederate. Consistent with a reluctance to form a social connection, participants in the late condition may have turned their attention away from the confederate thereby weakening or even eliminating the interpersonal coupling, and hence the resultant levels of coordination. This hypothesis, however, awaits empirical examination.

In a more general sense, the present results are consistent with a growing number of demonstrations of the spontaneous self-organization of synchronized action in interpersonal situations (e.g., Issartel, Marin, & Cadopi, 2007; Richardson et al., 2005; Richardson et al., 2007; Richardson, Lopresti-Goodman, Mancini, Kay, & Schmidt, 2008; Schmidt et al., 1990; Schmidt & O'Brien, 1997; van Ulzen et al., 2008; Zivotofsky & Hausdorff, 2007). This body of work highlights the utility offered by the application of a dynamical systems approach to elucidating the intricacies of interpersonal coordination. More specifically, acknowledgement that the *mode* of coordination has important implications for joint action, both in terms of setting a foundation for social interaction (e.g., Hove & Risen, in press; Miles et al., 2009) and influencing core aspects of social-cognitive functioning (e.g., Macrae et al., 2008) has primarily been derived from dynamical systems theories (e.g., Haken et al., 1985; Kelso, 1995; Kugler & Turvey, 1987; Schmidt & Richardson, 2008). Conversely, neural and representational accounts of behavioral coordination (e.g., Iacoboni, 2009; Rizzolati & Craighero, 2004; Prinz, 1997; Wilson, 2001; Wilson & Knoblich, 2005) provide a rich and arguably more fully developed insight into the mechanisms that support and constrain joint action. To this end, we see an integration of these complementary theoretical approaches (e.g., Tognoli et al., 2007) as a potentially valuable route to furthering the understanding of human social exchange.

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[7]It is possible that there was some auditory coupling via the sound of the confederate's footsteps, however this was minimised by the white noise played over the participant's headphones.

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