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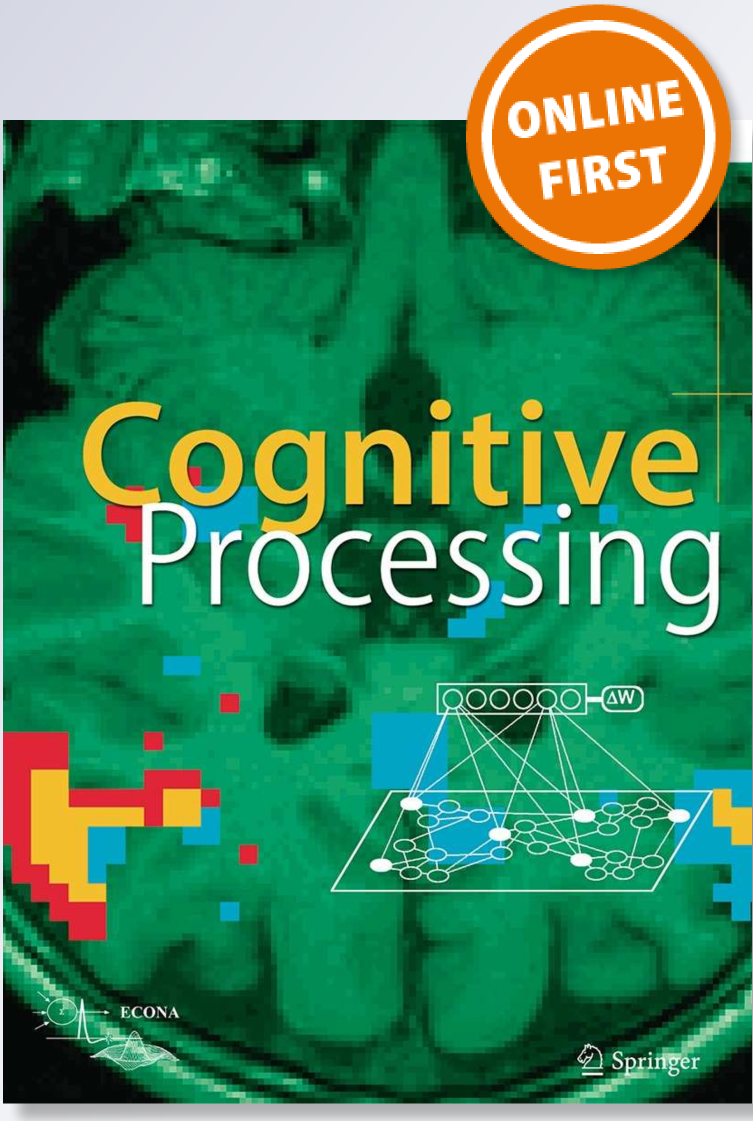

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RESEARCH REPORT

Movement dynamics reflect a functional role for weak coupling and role structure in dyadic problem solving

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Abstract Successful interaction requires complex coordination of body movements. Previous research has suggested a functional role for coordination and especially synchronization (i.e., time-locked movement across individuals) in different types of human interaction contexts. Although such coordination has been shown to be nearly ubiquitous in human interaction, less is known about its function. One proposal is that synchrony supports and facilitates communication (Topics Cogn Sci 1:305–319, 2009). However, questions still remain about what the properties of coordination for optimizing communication might look like. In the present study, dyads worked together to construct towers from uncooked spaghetti and marshmallows. Using cross-recurrence quantification analysis, we found that dyads with loosely coupled gross body movements performed better, supporting recent work suggesting that simple synchrony may not be the key to effective performance (Riley et al. 2011). We also found evidence that leader–follower dynamics—when sensitive to the specific role structure of the interaction—impact task performance. We discuss our results with respect to the functional role of coordination in human interaction.

Keywords Movement dynamics · Synchronization · Problem solving · Dyadic systems

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Introduction

When humans interact, the spatial and temporal structures of their behaviors become coordinated. A common intuition for interpersonal interaction is that behaviors that are more similar are probably better for smooth everyday conversation. This is sometimes referred to as synchronization. Generally, synchrony can be defined as a process in which two components tend to do similar behaviors within a specific temporal proximity (Schmidt and Turvey 1994; Shockley et al. 2002).

Indeed, there are many examples of interpersonal synchrony where *more* means *better*. Comprehension is higher when gaze paths are coupled (Richardson and Dale 2005), multimodal behavioral synchronization scales with task difficulty (Louwerse et al. 2012), and even simple motor synchrony increases affiliation (Hove and Risen 2009). However, recently, this intuition of *more is better* has been increasingly challenged. The *more is better* phenomenon is not universal (e.g., Fusaroli et al. 2012) and may start to break down when we ask: What is the function of interpersonal synchronization?

The question of functionality requires understanding the specific task constraints of the interaction, since functionality is always context dependent. For example, when two people are working together to solve a problem, they must maintain successful communication and subsequent comprehension. Therefore, for problem solving, the function for synchronization or interpersonal coordination broadly might be to aid in optimizing communication or even to serve as a form of communication in itself—a function proposed in and supported by previous work (e.g., Bavelas et al. 1986; Brennan et al. 2010; Shockley et al. 2009).

However, emerging research is adding nuance to the relation between synchrony and performance. In one study, increased overall linguistic synchrony (i.e., when partners generally used the same words) decreased performance, while increased *task-specific* linguistic synchrony (i.e., when partners only used the same words to describe stimuli) led to increased performance (Fusaroli et al. 2012). These empirical efforts mirror recent theoretical arguments that challenge researchers to think about synchrony *as well as* other forms of coordination (e.g., Riley et al. 2011). One such form may be *weak coupling*, in which individuals are not synchronized (or *strongly coupled*) but have fairly similar behavior patterns.

In the current study, we continue to challenge the universal *more is better* hypothesis. We do not dispute the large body of preceding research that has established synchrony's existence in a wide variety of settings over the past several decades (e.g., Condon and Sander 1974). While synchrony may provide clear conversational and social benefits like increasing affiliation (Hove and Risen 2009), the present study asks whether more is *always* better. For example, certain behavioral channels—like speech—require turn-taking for effective performance; if interlocutors were to continually speak over one another, we would not consider the speakers to be effectively communicating, although they would be synchronized.

Here, we present data analyzing dyadic performance during a somewhat complex but highly engaging task. We asked undergraduate student dyads to construct a tower structure out of a limited number of materials during a tightly constrained task. Specifically, dyads were tasked with building the tallest tower structure possible within 15 min using only uncooked spaghetti and marshmallows. To make the task more challenging, we only allowed one participant in each dyad to touch the spaghetti and the other participant to touch the marshmallows. In the present study, we analyzed participants' body movements—a commonly studied behavioral channel in the synchrony literature (e.g., Condon and Sander 1974; Louwerse et al. 2012; Shockley et al. 2009)—to determine whether synchrony (i.e., high behavioral similarly in time) or weak coupling (i.e., low behavioral similarity in time) better predicted performance in this joint task. This task was designed for a larger project studying the dynamics of dyadic problem solving beyond the local coordination dynamics observed in synchronization.

We expect that weak coupling would predict better performance than synchronization. Previous work hypothesizes that the organization of the dyadic system is a *soft assembly* of the constituent parts (Dale et al. 2013; Kello and Van Orden 2009; Riley et al. 2011): Individuals remain flexible and partially autonomous, but both are still constrained by the interaction and task goals (De Jaegher et al. 2010; Di Paolo and De Jaegher 2012; Fusaroli et al. 2014b). Under this expectation, a weakly coupled dyad would be constrained to the task but would be flexible enough to complement similar behaviors. Put differently, strongly synchronized dyads might be too rigid to adapt to evolving aspects of the task.

Finally, we also expect to find evidence of leader–follower movement dynamics—or rather, a clear temporal organization of roles—within high-performing dyads. There are two defined roles in our task: a spaghetti holder and a marshmallow holder. In order to perform as best as possible, the dyadic system might reorganize itself around the roles the task imposed as constraints on the system. Therefore, if role structure is a functional component of the dyadic system, we would expect that dyads with a defined temporal organization of roles—that is, one leader and one follower—to perform better. In a construction task with strongly imposed constraints, dyads with a clear temporal organization of roles may outperform dyads with a more uniform temporal organization between members of a dyad.

Method

Participants

Fifty undergraduate students (mean age = 19.32 years) at the University of California, Merced, participated as 25 dyads in return for extra course credits. Participants individually signed up using the anonymous online subject pool system and could not see their partner's identity before arriving at the study. Dyads included female–female ($n = 12$), male–male ($n = 4$), and mixed-sex ($n = 9$) pairings.

Materials and procedure

Participants completed brief surveys including demographic questionnaires upon arrival. Once completed, participants were asked to sit in one of two stationary chairs near a square Table (76.2 cm L by 76.2 cm W by 71.1 cm H). Seating arrangement was participant-initiated, and the experimenter did not provide any explicit direction toward any of the two chairs. The two chairs and table were orientated such that the chairs were placed adjacent to each other, with the table rotated 45° in line of sight of the camcorder (tripod-mounted Canon Vixia HF M31 HD camcorder).

Once seated and outfitted with Shure Beta 54 supercardioid microphone headsets,[1] participants were given task instructions. Participants were instructed to construct the tallest tower structure possible within 15 min using only the materials provided: one box (~10 oz) of large

[1] Audio data were not included in any analyses reported here.

marshmallows and one box ($\sim$1 lb) of raw spaghetti. To enforce interaction, only the participant seated on the right was allowed to touch the marshmallows, and only the participant seated on the left was allowed to touch the spaghetti. They were not allowed to use partial or broken pieces of material, and participants were to immediately remove any pieces of material that broke during construction. Both participants were to remain seated during the task. The experimenter monitored these rules during construction and reminded participants if they violated any of these rules.

After answering any questions, the experimenters started the task. Participants were permitted to talk freely during construction. During construction, one experimenter provided 5- and 1-min warnings. Once the time limit expired, the experimenters recorded the height of the tower with participants present and recorded the weight of the tower after the participants left.

After the tower's height was measured, participants were separated and individually answered four questions about perceptions of the roles of marshmallow and spaghetti holders. Each question asked participants to rate the levels of dominance and passivity of a single person or type of person using a Likert-style scale: *1*—mostly passive; *2*—somewhat passive; *3*—somewhat dominant; or *4*—mostly dominant. The first two questions asked participants to rate themselves ("During this task, I felt like I was…") and their partner ("During this task, I felt like my partner was…"). The second two questions asked them to separately rate the dominance/passivity of the marshmallow and spaghetti holders more broadly ("For most people who complete this task, I feel like the role of [*marshmallow/spaghetti*] holder would be…" as separate questions). This provided a subjective quantification of participants' perceptions of and expectations about the distribution of power during the task.

Movement analyses

Using Apple iMovie, video files were truncated to contain only interactions occurring during the 15-min task. These truncated video files were analyzed using a frame-differencing method (FDM) to obtain time series of standardized movement scores for each participant based on changes in pixel from frame to frame (for details on method, Paxton and Dale 2013). The FDM provided an objective measure of overall body motion taking place, without reference to specific limbs or directions. With the FDM, higher numbers of the standardized movement scores indicated higher amounts of *overall* movement for that participant.

The automated method required us to remove the centermost portion of each frame from analysis: because participants' movement frequently overlapped in this shared space, including the center portion would have conflated participants' movement, we chose to concentrate analysis on the head, body, and upper arms of each participant. That is, we were interested in the general patterns of movement *beyond* simply the task-relevant hand placement and movement. For these analyses, we wanted to investigate whether and how overall movement patterns—without including specifically task-constrained movement dynamics—might reflect task structure and performance. Our past work has demonstrated that this basic measure of gross body movement is sufficient to reveal systematic and interesting dynamic signatures relating to task and social variables (Paxton and Dale 2013).

Performance and social data

After analyzing the video data, we computed various performance and social measures. The performance metric was computed as the ratio of height to weight of the tower structure. This measure captured the performance of the problem-solving task relative to the materials used, creating an efficiency measure. This measure was used due to relatively small variability in the height variable alone. The efficiency performance metric exhibited higher variability and a more normal distribution. For the social measures, we then created three variables to account for gender distribution, perception of role distributions, and perception of role division. The gender distribution measure was created as a 3-factor variable indicating whether a dyad was a female–female, male–male, or mixed-gender dyad.

For the perception of role distribution measure, we calculated a dyad-level dominance score by taking the sum of each participants' perceived dominance rating for the higher rated role (spaghetti or marshmallow) divided by the sum of each participants' perceived dominance rating for the lower-rated role (spaghetti or marshmallow). Larger values indicated that the dyad (overall) believed that there was a particular role (either spaghetti holder or marshmallow holder) that was more dominant. Smaller values indicated that the dyad believed there was less of a structured system of roles. Generally, however, we interpreted higher values of the perception of role distribution measure as an endorsement of an asymmetric role structure, while lower values were interpreted as endorsement of a stronger egalitarian role structure.

For the perception of role division, we calculated a dyad-level score by taking the absolute difference score of each participant's perceptions of each other's dominance during the interaction (i.e., first pair of questions on the role questionnaire). Higher values of the perception of role division measure indicated the dyad implicitly disagreed about the power dynamics of the dyad, expressing *dissimilar* views about one another's dominance. Lower values indicated the dyad implicitly agreed about the power dynamics, endorsing compatible role ratings about themselves and one another.

Cross-recurrence quantification analysis

Cross-recurrence quantification analysis (CRQA) is a technique used to compare the temporal patterns of two complex systems, often used as a measure of synchronization or coordination (Coco and Dale 2014). At the most basic level of description, CRQA measures the extent to which signals exhibit similar patterns through time. Mathematical descriptions of the analysis have been documented extensively elsewhere (Coco and Dale 2014; Fusaroli et al. 2014a; Marwan et al. 2007); therefore, we limit our description to be merely conceptual.

Broadly, CRQA provides information about how often two signals co-visit a state space that is inferred from the observed time series. When two signals co-visit the same areas of a state space at approximately the same time, the signals' increased temporal coordination is reflected in high rates of recurrence. However, CRQA can also investigate long-range patterns of influence across two signals by quantifying the similarity of signal patterns that are separated in time.

For this report, we performed diagonal-wise cross-recurrence (DWCR) of the two continuous standardized movement signals from each dyad. We utilized the drpdfromts function from Coco and Dale's (2014) crqa R package (R Core Team 2012) and set the window size to ±10 s and radius to .02. Considering our interest in synchronization and weak coupling as a function of shorter or longer lags, we chose a window size of ±10 s to capture a wider temporal window than found in previous work using CRQA (e.g., Louwerse et al. 2012). We chose a radius parameter of .02 because we wanted to use a conservative measure of recurrence. Note that we are using continuous signals of standardized (i.e., z-scores) movement signals. Therefore, for two signals to be considered recurrent, the change between both signals required the signals to be, at most, .02 standard deviations from each other. The DWCR analysis returns the recurrence between two signals at various delays: the maximum recurrence observed (MAX REC) and where MAX REC occurred (MAX REC LAG). DWCR provides something akin to a cross-correlation function, but it does not only rely on linear patterns of relationship between the time series (Marwan et al. 2007).

Results

Surrogate (baseline) analysis

To assess synchronization, or the degree of synchronization, it is important to first assess the differences between observed dyads and random pairings of dyads. By establishing a baseline of synchrony through surrogate analysis (also called virtual pairs analysis; e.g., Dale et al. 2011), we can compare properties of the observed dyadic interactions against what might be expected by chance.

For the surrogate test, we created "surrogate dyads" by randomly pairing members of each dyad with members of other dyads with whom they *did not actually interact*. This provided a baseline for the rates of recurrence that could be expected by chance or the amount of similarity of behavior that we might expect simply as a function of the environment or task rather than the actual process of interaction. We created 400 non-repeated surrogate dyads and then performed DWCR on each pairing to estimate recurrence profiles.

To statistically compare the rates of recurrence between observed dyads to random surrogate dyads, we performed a Welch two-sample t test on the average recurrence profiles for the observed dyads and surrogate dyads. Average recurrence for the observed dyads ($M = .61$, $SE = .001$) was reliably higher than the average recurrence for the surrogate dyads ($M = .58$, $SE = .001$), $t\ (162.58) = -30.43$, $p < .001$ (see Fig. 1). We can therefore conclude that the observed levels of interpersonal coordination, as viewed through the CRQA analyses, are significantly above chance levels.

Strong synchronization or weak coupling?

As discussed earlier, we were interested in first uncovering what degree of synchronization in movement would be more likely to result in better dyadic performance. To test this, we constructed a linear regression model predicting performance with each dyad's maximum recurrence (MAX REC) and the lag at which MAX REC occurred (MAX REC LAG). If synchrony were more important, we would

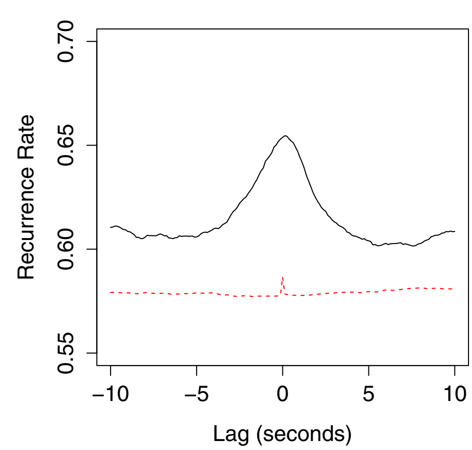

Fig. 1 Aggregated cross-recurrence for movement behavior for observed (*black*) and surrogate (*red*) dyads (color figure online)

expect to find a significant interaction term between MAX REC and MAX REC LAG, in which higher performance would be predicted by higher levels of MAX REC at lower (i.e., shorter) MAX REC LAG. This would suggest that better-performing dyads exhibited similar amplitudes of movement more closely in time. However, a significant effect of lower MAX REC would suggest that dyads with less similar behaviors—that is, weakly coupled dyads—perform better.

As predicted by the weak coupling hypothesis, recurrence (MAX REC; $\beta = -.37$, $p = .05$) negatively predicted performance, suggesting that lower movement similarity resulted in higher performance overall. This result was qualified by an interaction effect trending toward significance (see Fig. 2) between MAX REC and MAX REC LAG ($\beta = -.33$, $p = .07$). Dyads with shorter MAX REC LAG show no difference in performance, regardless of MAX REC. However, dyads with more removed MAX REC LAG differ in performance based on their rates of recurrence: while dyads with lower recurrence (i.e., MAX REC) perform as well as individuals with longer MAX REC LAG and dyads with higher recurrence perform more poorly.

The results from this model support the general notion that strong synchronous body movements do not facilitate greater performance during a dyadic problem-solving task. Notably, these results provide preliminary evidence for the notion that more loosely coupled movement dynamics might be more beneficial than simple synchrony during certain types of interactions. This parallel similar results

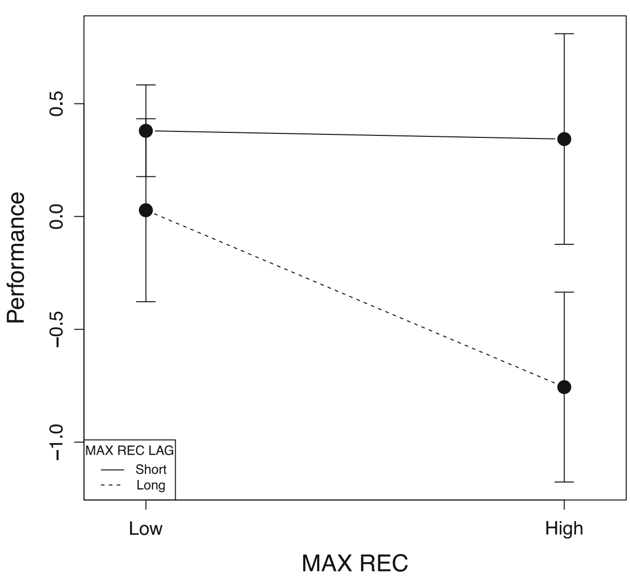

Fig. 2 Interaction between MAX REC LAG and MAX REC. Plot shows median split of standardized MAX REC (*low*/*high*) and MAX REC LAG (*short*/*long*) variables. Performance is centered and standardized

found in analyzing linguistic coordination during task-based interactions, suggesting that so-called *indiscriminate* coordination of behaviors may not always be the most optimal behaviors (Fusaroli et al. 2012).

It is also possible that the movement dynamics vary as a function of a number of external properties, like the dyad's gender composition and perceptions of role distribution and power. Therefore, we included these variables in all subsequent models. Hereafter, data were analyzed using linear mixed-effects models with gender composition, perception of role distribution, and perception of role division as random intercepts due to failure to converge with fully specified random effects structure (cf. Baayen et al. 2008).

We then created an additional model—controlling for these external variables—that tested the same hypothesis as the linear regression model described above: whether weak coupling of body movements facilitates performance. We again found that performance decreased with higher MAX REC ($\beta = -.27$, $p = .007$) and that the interaction effect between MAX REC and MAX REC LAG now reached significance ($\beta = -.35$, $p = .0001$). Again, the poorest performers were individuals whose high recurrence (i.e., MAX REC) occurred at longer lags (i.e., longer MAX REC LAG).

These results replicate the results found in the simple linear regression model reported above while controlling for external properties and strengthen the notion that weak coupling may facilitate performance, compared with simple patterns of strong synchronization (see Appendix for identical analyses for the height performance measure). If synchronization were the optimal pattern of behavior for this task, we would not expect to see these patterns of results. Overall, dyads with more loosely coupled movement patterns performed better than dyads with more strongly coupled movements.

Leader–follower dynamics

To investigate the temporal organization of roles of each dyad, we first computed the absolute difference of the participants' recurrence profiles, creating a *role-agnostic* quantification of the temporal structure of role patterns reflected in movement dynamics. This measure—the absolute leader–follower (ALF) score—was computed by taking the absolute difference score of the sum of the recurrence profile for the marshmallow holder role subtracted from the sum of the recurrence profile for the spaghetti holder. Because higher values of recurrence for each individual are indicative of more "leading" behavioral patterns for that individual, higher ALF values would suggest increasingly strong temporal organization dynamics of movement patterns. However, in a linear mixed-effects model including dyad's gender composition, perceptions of role distribution, and power as random effects, ALF did not predict performance ($\beta = -.08$, $p = .64$), suggesting that simply having a behavioral leader during the task neither positively nor negatively affected the dyad's performance.

Although the *magnitude* of a temporal organization dynamic did not impact performance, it is possible that the specific *role structure* of the dyad's temporal organization dynamic matters for subsequent performance. Therefore, we computed a new measure—the role-specific leader–follower (RSLF) score—as a role-sensitive metric of temporal organization dynamics. RSLF was computed by subtracting the sum of the recurrence of the spaghetti holder from the sum of the recurrence of the marshmallow holder. For each dyad, a negative RSLF value would indicate that the marshmallow holder had led the movement dynamics, while positive values would indicate that the spaghetti holder had led the movement.

In contrast to the ALF results, RSLF moderately predicted performance, although the effect only trended toward significance with the current sample size ($\beta = -.28$, $p = .068$). Furthermore, the intercept was not reliably different from zero, ($\beta = .17$, $p = .66$), indicating that, overall, dyads did not demonstrate an organized role structure with movements. That is, across all dyads, neither the spaghetti holder nor the marshmallow holder tended to initiate movement patterns. Although the model using RSLF (AIC: 77.26) only moderately predicted performance, the model fit reliably better than the model of ALF (AIC: 79.26) predicting performance, X^2 $(6) = 2.17$, $p < .001$. While simply *having* an organized temporal structure of roles did not affect performance, dyads performed *moderately* better when the marshmallow holder led the movement dynamics.

Discussion

First, like many prior studies, the results from the current study demonstrate that individuals tend to synchronize with their partners during interaction. In keeping with the large body of existing research (e.g., Bernieri et al. 1988), the surrogate (or baseline) analysis demonstrated that movement synchronization was stronger for interacting dyads than virtual dyads. Establishing that synchrony occurred above chance for interacting dyads is important for subsequent interpretations of the results. It also suggests that even if patterns of movement are similar across interlocutors from all dyads—as might be expected with common task constraints and physical location—the temporal coordination of these patterns were *specific* to each dyad. In a sense, the constraint of interacting with a specific partner was stronger than the constraints of the task, again supporting preceding work demonstrating that interacting individuals' patterns of synchrony are unique to that interaction and that partner (Bernieri et al. 1988).

The *more is better* hypothesis would predict that stronger synchronization should lead to better performance. However, we observed that *weaker* synchronization predicted better performance: Dyads above the median MAX REC had a standardized performance score of $-.21$ ($SE = .34$), while dyads below the median MAX REC had a standardized performance score of .14 ($SE = .25$). This suggests that a loosely coupled problem-solving dyadic system may be functionally optimal for tasks with strong external constraints, allowing the dyad to flexibly adapt to new challenges while nevertheless staying on the same "wavelength" as their partner.

Furthermore, the magnitude of coupling did not matter when movements were in close temporal proximity. However, when movements occurred with more temporal delay, stronger coupling (i.e., recurrence) led to poorer performance. In other words, some dyads closely repeated each other's movement behaviors but at an extended time lag, and this led to decreased performance. We interpret this result as evidence for the benefits of loosely coupled dynamics during interpersonal coordination.

Although the patterns did not quite reach significance, we found strong trends pointing to the importance of a role-dependent temporal organization dynamic for improved performance. A temporal organization measure that was agnostic to role structure did not predict performance. However, when accounting for the roles of the dyad, performance improved when the marshmallow holder was the leader of movements, suggesting that the emergence of role-sensitive temporal organization may be vital to effective performance in highly constrained in dyadic problem solving.

It is important to note the limitations of the current study. Task instructions were to build the tallest tower structure possible within a specific temporal duration. Given the small variability of the height-dependent variable, we chose to use a measure of efficiency: the height-to-weight ratio of the structure. Although efficiency was not a direct measure of performance as per task instructions, considering the task constraints of limited materials and limited time, it can be viewed as an implicit measure of building the tallest tower structure possible within the specific task constraints. Of course, the performance measure used in the current study was computed post hoc, so we are limited in the interpretations of our results.

While the present study focuses specifically on dyadic task performance, we believe it contributes to ongoing questions about the nature and function of interpersonal coordination and synchronization. The *more is better* hypothesis has been the predominant view of coordination since the field's emergence (e.g., Condon and Sander 1974). However, a growing cluster of empirical evidence (e.g., Fusaroli et al. 2012) and theoretical arguments (e.g., Riley et al. 2011) has begun to add nuance to this view, calling attention to the context dependence of human interaction and interpersonal coordination. The present findings support this view: Coordination appears to support interaction goals, providing a scaffold that varies with the needs of the interaction. Some goals may be better supported by strong coupling (e.g., Richardson and Dale 2005), while others—like those in the current paper—may instead be better achieved through more flexibility. As additional research continues to map out the nature of coordination across various types of interaction, we may be better able to understand its function in communication more broadly.

Future directions

Two related questions arise from our results about temporal organization of movements and role structure: (1) what is the function of having role structure, and (2) what is the benefit of having the marshmallow holder take a more active role in leading the movement dynamics? The mere observation of role structure does not imply that it is functional. However, when role structure predicts performance—that is, whether it is a spaghetti-leading or marshmallow-leading temporal organization—there is reason to suspect that role structure may be functional for the interaction. In the introduction, we presented the view that the function of interpersonal coordination and synchronization might be for optimizing communication (Shockley et al. 2009). We now add that role structure might facilitate the degree to which synchronization is functionally relevant for optimizing communication, at least during task-directed interaction.

Why did having the marshmallow holder lead the movement coordination of movement facilitate better performance? This question becomes even more intriguing when considering participants' perceptions of the dominance of each of the two roles. Overall, regardless of their own role, all participants perceived the marshmallow holder to be more passive and the spaghetti holder to be more dominant, $p < .001$.

Given this perception and the dynamics of the task, we believe that the marshmallow-leading dynamic may be modality specific. When solving a problem together, especially when constructing a tower structure, speech and movement are intertwined (Paxton and Dale 2013). People tend to communicate plans for construction through speech, and these plans are acted upon with movements. Speech, then, may be leading movement across the dyad. If so, the perception of spaghetti-holder dominance may be grounded in leading in the speech modality, with the spaghetti holder more often directing the upcoming action. In that case, the marshmallow holder would then initiate movements in response to these directions, registering as the leader in the movement data in spite of the spaghetti holder's leading in the speech data. Future analyses will examine patterns of synchrony in speech and cross-modal analyses to better understand the basic dynamics of the interaction and to reconcile participants' perceptions with the objective behavioral metrics.

These patterns may also be affected by the nature of the current task. Dyads tended to use marshmallows as a bonder or as joints for the spaghetti. Anecdotally, the marshmallow holder often moved first to put the joint in position before their partner placed the spaghetti. This explanation is complementary with the ideas mentioned above, but it is important to again emphasize the context dependence of functionality when interpreting our results. What is considered functionally optimal in tasks with strong external constraints may be suboptimal for other types of tasks.

Conclusion

Here, we contribute to the growing interest in the function of interpersonal synchrony. Our results continue to question the *more is better* hypothesis about synchrony: Dyads with weakly coupled movement behavior performed better on a problem-solving task than those who strongly synchronized with one another, perhaps because the weak coupling granted additional flexibility to adapt to task constraints. We also found evidence that strong temporal organization of role structure—when sensitive to contextual demands—may be an adaptive response leading to better performance. These results reinforce emerging views that the dyadic system involves complex dynamics (Abney et al.2014) and that *more* (synchronization) is not always *better*.

Appendix

For the height measure of performance, a linear regression analysis suggested that recurrence (MAX REC; $\beta = -.34$, $p = .10$), MAX REC LAG ($\beta = -.05$, $p = .81$), nor the interaction ($\beta = .09$, $p = .66$) predicted performance. For the height measure of performance, a linear mixed-effects model predicting performance (using gender composition, perception of role distribution, and perception of role division as random intercepts) suggested that performance decreased with higher MAX REC ($\beta = -.39$, $p = .05$). No other main effects or interactions were significant ($ps > .05$).

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