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Authors

Paxton, Alexandra

Dale, Rick

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Multimodal Networks of Interpersonal Interaction and Conversational Contexts

Alexandra Paxton (paxton.alexandra@gmail.com)

Rick Dale (rdale@ucmerced.edu)

Cognitive and Information Sciences, University of California, Merced
Merced, CA 95341 USA

Abstract

In interpersonal interaction, the terms *synchrony* or *alignment* refer to the way in which communication channels like speech or body movement become intertwined over time, both across interlocutors and within a single individual. A recent trend in alignment research has targeted *multimodal* alignment, exploring how various communication channels affect one another over time (e.g., Louwerse et al., 2012). While existing research has made significant progress in mapping multimodal alignment during task-based or positively valenced interactions, little is known about the dynamics of multimodal alignment during conflict. We visualize multimodal alignment during naturalistic affiliative and argumentative interactions as networks based on analyses of body movement and speech. Broadly, we find that conversational contexts strongly impact the ways in which interlocutors' movement and speech systems self-organize interpersonally and intrapersonally.

Keywords: alignment; conflict; conversation; interaction; movement; network; speech; synchrony

Introduction

Interpersonal communication is a multimodal activity. Conversation incorporates multiple channels of communication that enrich the interaction, like hand gestures, facial expressions, posture, and speech. To effectively communicate with one another, interlocutors cue in to each of these channels simultaneously, often without realizing the importance placed on each of them.

Considerable work has surveyed multimodal qualities of interaction (e.g., Norris, 2004). However, in general, experimental study of interpersonal communication in cognitive science tends to target single behavioral channels. This has led to significant advances in our understanding of these specific channels, but there is still much work to be done in investigating the connections among them. Continued multimodal research will likely yield interesting—and possibly unexpected—relationships among channels that have been extensively explored unimodally. For this reason, the current research explores multimodal alignment situated within different conversational contexts.

Specifically, the present research examines interpersonal communication through alignment dynamics. Research on interpersonal alignment focuses on how affect, behavior, and cognition of interacting individuals affect one another over time. Over the past several decades, researchers have explored interpersonal alignment over a range of channels, from movement (e.g., Richardson et al., 2007) to speech (e.g., Garrod & Pickering, 2004) to cognition (e.g., Brennan, Galati, & Kuhlen, 2010). As aforementioned, the majority

of this work centers on one or two behavioral channels, but a growing body of literature has begun to investigate how multiple channels align during communication (e.g., Louwerse, Dale, Bard, & Jeuniaux, 2012).

A distinction can be drawn between *alignment* in a general sense and *synchrony*.¹ We use the term alignment to refer broadly to the concept that individuals, over time, change their affect, behavior, and cognition as a direct result of their interaction with another individual. This umbrella term encompasses everything from mimicry, in which individuals are performing highly similar behaviors to their interaction partner (e.g., Chartrand & Bargh, 1999), to more complementary behavior patterns like synergy (e.g., Riley, Richardson, Shockley, & Ramenzoni, 2011). Synchrony, on the other hand, can be considered a specific pattern of alignment and refers exclusively to the in-phase entrainment of behavior or communication channels.

In the spirit of intrapersonal alignment research spanning the last several decades (e.g., Haken, Kelso, & Bunz, 1985), the current research explores the dynamics of interpersonal alignment as a self-organizing property of human interaction. The present research focuses specifically on two channels of communication—speech and body movement—and the ways in which these channels are affected by each other, by conversation partners, and by the conversational context. If it is true that human interaction self-organizes around, for example, conversational goals, we should expect to see multimodal alignment patterns changing across these different contexts.

Body Movement and Speech Alignment

Previous work on speech and body movement demonstrates rich interactivity between and within individuals. Some of the earliest work in alignment research presents evidence for interpersonal and intrapersonal multimodal alignment between movement and speech channels (Condon & Ogston, 1966). Since then, research has continued to explore intrapersonal alignment, both in speech (Reitter, Moore, & Keller, 2010) and movement (Beek, Peper, & Daffertshofer, 2002). However, body movement and speech have both been studied extensively within the interpersonal alignment literature as well, generally within affect-neutral, positively valenced, or task-oriented settings.

Studies of body movement alignment have spanned a wide variety of behaviors, including gesture (Bernieri &

¹ These specific terminologies are laid out here for the purpose of the present paper, rather than trying to resolve the emerging terminological debate within the field.

Rosenthal, 1991), stepping (Miles, Griffiths, Richardson, & Macrae, 2010), and overall levels of body movement (Paxton & Dale, in press). Often, work on body movement alignment incorporates elements of social psychology, like investigating how interpersonal alignment affects liking (Chartrand & Bargh, 1999). Broadly speaking, these findings generally cast the phenomenon as a pervasive and relatively automatic process that can be enhanced with liking or rapport. However, limited research suggests that higher-level social factors may inhibit bodily alignment (Miles et al., 2010; Paxton & Dale, under revision).

Individuals also align over numerous measures of speech. Over time, interacting individuals have been shown to use more similar acoustic features (Kousidis & Dorran, 2008), sentence structures (Cleland & Pickering, 2003), and even respiratory patterns (McFarland, 2001). The tendency toward alignment during interaction is so powerful that individuals even align to simulated partners (Krämer, Kopp, Becker-Asano, & Sommer, 2012). These and related findings of interpersonal alignment in speech have led some to suggest that this is an automatic tendency driven in part by shared cognitive representations (Brennan et al., 2010).

These past findings point to a distinct temporal structure of speech and movement during interaction. Recently, researchers have begun to emphasize the importance of investigating interpersonal multimodal alignment on a large scale (e.g., Delaherche & Chetouani, 2010; Louwerse et al., 2012). These questions allow researchers to more fully understand the complex, interdependent structure of communication channels during interaction.

Dynamics of Interpersonal Alignment

Mechanistic models of body mechanics (e.g., interlimb coordination; Haken et al., 1985) have influenced recent work on the dynamics in interpersonal interaction (e.g., Miles et al., 2010). Researchers have begun to explore the forms and functions of alignment, going beyond earlier studies simply investigating its existence. Such work is dedicated to exploring the time course of alignment with the belief that—like many other phenomena—alignment is neither static nor uniform across contexts.

Like the work discussed above, research on interaction dynamics has also focused on speech and movement channels. From gaze patterns and postural sway (Shockley, Richardson, & Dale, 2009) to speech production (Tilsen, 2009), researchers have found support for dynamical interpersonal and intrapersonal alignment, both unimodal and multimodal. Individuals' patterns of alignment change with task demands (Sebanz, Bekkering, & Knoblich, 2006), social context (Miles, Lumsden, Richardson, & Macrae, 2011), and even physical environment (Richardson et al., 2007), providing further support for claims of context dependence in alignment (Riley et al., 2011).

The Present Study

Previous work has pointed to distinct patterns of organization of speech and body movement between and

within individuals, and recent trends have begun to situate this alignment within the context of multimodal interaction. Yet, so far, the dynamics of multimodality in alignment have remained relatively unexplored. Moreover, research on alignment thus far has sampled only a small percentage of the total space of human communicative contexts, focusing primarily on task completion or friendly interactions.

Our primary goal in the present study is to add to the growing literature on the dynamics of multimodal alignment. We aim to extend various elements of previous findings on unimodal and multimodal alignment, both inter- and intrapersonally. The present study explores participants' speech patterns and their relation to body movement with three initial hypotheses. First, we hypothesize that individuals will align to one another's speech patterns but will not demonstrate in-phase synchrony of speech, due to the natural constraints of turn-taking. Second, we anticipate that individuals will exhibit multimodal intrapersonal synchrony, tending to move and speak at the same time. Third, although we anticipate that individuals will be most likely to move while speaking (and the reverse), we expect that analyses will reveal some evidence for interpersonal multimodal alignment (e.g., due to nodding).

The current project extends previous work on multimodal alignment further by situating the research within different conversational contexts, namely affiliation and argument. As part of a larger line of research investigating alignment in various contexts, the present research brings a focus on asymmetric contexts—interactions in which individuals have conflicting, differing, or opposing goals—to bear on questions of multimodal alignment. Previous research has demonstrated that conflict significantly decreases levels of interpersonal bodily synchrony (Paxton & Dale, under revision). We continue to explore alignment during conflict in the present project. Compared to non-asymmetric contexts, we anticipate that argument will affect alignment in several ways: first, that individuals will demonstrate a more rigid turn-taking structure (possibly, e.g., to satisfy implicit social demands for reciprocity); second, that levels of intrapersonal multimodal synchrony will remain consistent; and third, that levels of interpersonal multimodal alignment will decrease. This pattern of results—balancing stable conversational structures with sensitivity to contextual factors—would reinforce claims of context-dependent, emergent properties of human interactions.

In addition to analyzing these data, the present study also hopes to begin work towards descriptive models of interpersonal and intrapersonal multimodal and unimodal alignment in different conversational contexts. After presenting our analyses, we highlight our findings in visualization networks of multimodal alignment dynamics.

Method

Corpus

The data presented here were collected by the authors as part of a larger corpus comparing interpersonal alignment

during argument and affiliation. The corpus comprised over 35 naïve participant dyads engaged in different conversational settings, collected from the University of Memphis and the University of California, Merced. As a further exploratory analysis building on previous findings (Paxton & Dale, in press; Paxton & Dale, under revision), the present analyses were performed on a subset of the participants from the University of California, Merced, based on uniformity of experimental conditions. The audio data had not yet been analyzed, separately or in conjunction with body movement.

Participants

24 undergraduate participants (mean age=20.14 years) were recruited as 12 dyads (6 female, 6 mixed-sex) through the school's online subject pool system. Participants signed up independently and were unable to see their partner's identity beforehand. Only one dyad reported having known one another prior to participation. One mixed-sex dyad was dropped from present analyses because their opinions were too similar to achieve any argument during the experiment.

Procedure

Upon arrival, participants were separated and individually completed a number of questionnaires prior to interacting with one another. One of the questionnaires was an opinion survey that included a number of sociopolitical (e.g., abortion, death penalty, legalization of marijuana) and university-specific (e.g., a campus rule forbidding freshmen students from bringing cars to campus) issues. The opinion survey posed the issues as open-ended, opinion-neutral questions. For each item, participants were given several lines to write their opinion and were directed to indicate the strength of that opinion on a Likert-style scale from 1 (*feel very weakly*) to 4 (*feel very strongly*).

Participants were randomly assigned to one of two conditions based on the order of the two target conversations that they were prompted to have. All dyads held a brief introduction conversation without the experimenter present (~3min) and two target conversations (10min each). Half of the dyads were given an affiliative prompt first and an argumentative prompt second; half of the dyads experienced the reverse order. After each target conversation, participants were separated to complete post-conversation measures. Participants were not informed in advance of the conversation topics. After holding both target conversations, participants were thanked and debriefed.

For the affiliative conversation, dyads were instructed to discuss popular media that both participants enjoyed.² Experimenters identified the argumentative prompt for each dyad based on participants' responses to the opinion survey. The topic for which participants expressed

opposing views (e.g., one pro-life, the other pro-choice) and for which both participants indicated strong feelings was chosen. Up to two additional argumentative prompts were chosen using the same criteria and were given to participants if they could not continue the argumentative conversation on the first topic for the entire time.

Materials

Movement data were collected automatically using a frame-differencing method (FDM; Paxton & Dale, in press). Participants sat facing one another during their conversations and were captured in profile in a single frame on a high-definition camcorder (Canon VIXIA HF M31).³ The videos were downsampled at 8Hz to a series of still frames. The FDM tracked movement by registering changes in pixels across frames (see Figure 1 for toy visualization) and applying a filter to remove extraneous pixel changes (e.g., due to fluctuations in light sources). For additional detail on the FDM, see Paxton and Dale (in press). See also Grammer, Honda, Jüette, and Schmitt (1999) for related methods.



Figure 1: Sample FDM sequence of interacting dyad, aggregated over multiple frames for visualization purposes.

Speech data were collected using individual lapel microphones (Audio-Technica ATR 3350) and a mixer (Azden CAM-3) so that each participant's audio was captured on a separate channel. The present research used on/off speech states as the measure for speech. On/off speech states were obtained for each participant using the sound finder function in Audacity. Decibel cutoffs were individually determined for each dyad in order to maximize sensitivity and specificity.

Samples of data obtained from each interaction type are graphed in Figure 2. Each sample includes 250sec of interaction. Taken from the same dyad, the figures graph changes in body movement as red and blue lines, with speech events depicted as boxes of corresponding color behind the lines.

Results

The present analyses tested for unimodal and multimodal interpersonal and intrapersonal alignment. Cross-correlations were calculated for interpersonal unimodal (e.g., participant A's movement to participant B's movement), interpersonal multimodal (e.g., participant A's speech to participant B's movement), and intrapersonal

² Due to experimenter error, one dyad's affiliative prompt was based on a sociopolitical topic on which both agreed. However, close inspection of the data confirmed the affiliative nature of the conversation.

³ The experimenter sat beside the camcorder, outside of the participants' immediate range of vision, in order to monitor the equipment unobtrusively and to ensure the participants did not stray from the assigned topic.

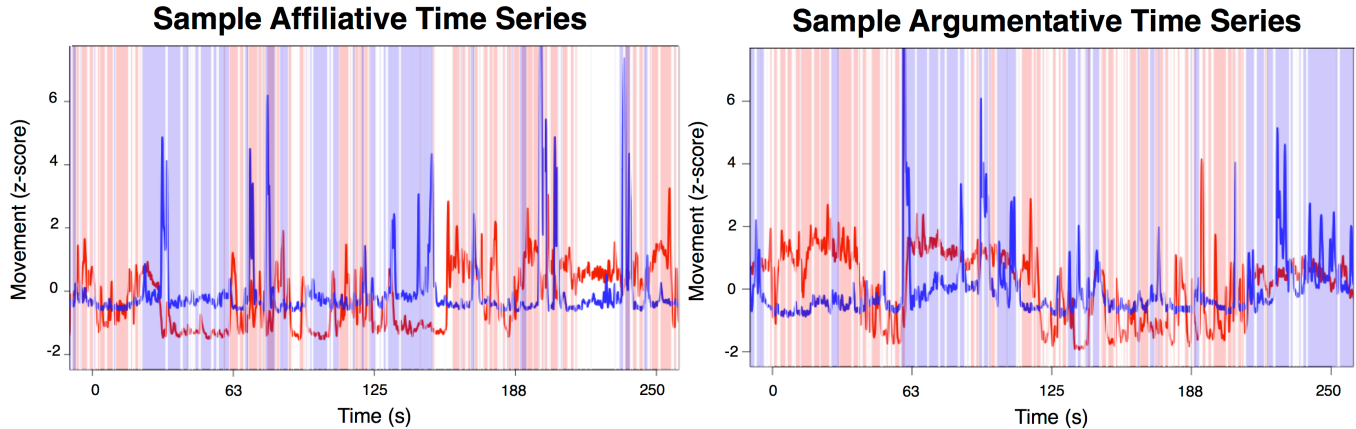


Figure 2: Sample body movement time series of a single dyad during 250s of interaction during an affiliative (left) and an argumentative (right) conversation. Speech data are represented as shaded boxes of corresponding colors.

multimodal (e.g., participant A's movement to participant A's speech) channels within a ± 3000 ms range, yielding a series of cross-correlation coefficients (r). Using cross-correlation coefficients permitted us to investigate both in-phase synchrony and longer-phase alignment trends within the data.

The data were primarily analyzed using a series of linear mixed-effects models (Baayen, 2008), using dyad and condition as random effects unless otherwise noted. All main and interaction terms were standardized prior to being entered into the models. As standardized values, the cross-correlation coefficients can be interpreted as beta weights, a measure of effect size (Keith, 2005).

Unimodal Alignment

Movement Previous analyses of the corpus found evidence for in-phase bodily synchrony (Paxton & Dale, under revision).⁴ To ensure that the subset analyzed here exhibited similar patterns, our first model predicted interpersonal body movement alignment (r_{mov}) with conversation type (affiliative or argumentative) and time lag (125ms increments). Results confirmed that the subset of dyads conformed to broader patterns within the whole corpus. Increases in time lag (i.e., comparing movement further removed in time) significantly predicted a drop in r_{mov} ($\beta = -.25$; $p < .0001$), providing evidence for in-phase interpersonal synchrony. Changes in r_{mov} were also significantly predicted by conversation type ($\beta = -.19$; $p < .0001$), with lower levels of movement synchrony in argumentative conversations. Interestingly, while only trending toward significance in analyses of the entire corpus, the interaction term between conversation type and time lag reached significance in this subset of the data ($\beta = .14$; $p < .01$): Interlocutors' body movements were more tightly synchronized during affiliative conversations, reaching higher peak r_{mov} and falling more sharply as time lag increased.

⁴ One dyad included in the present analyses was excluded from analyses in Paxton and Dale (under revision), due to incomplete data for other analyses.

Speech The second model tested interpersonal speech alignment during different conversation contexts, using conversation type and time lag (125ms) to predict interpersonal speech alignment (r_{speech}). As anticipated, increases in time lag predicted increases in r_{speech} ($\beta = .15$; $p < .0001$), while argumentative conversation type significantly predicted a decrease in r_{speech} ($\beta = -.44$; $p < .0001$). The interaction term was also significant ($\beta = .11$; $p < .001$). Together, these results suggest that interlocutors generally respected the turn-taking structure during all conversations but were more likely to exhibit overlapping speech during affiliative conversations.

To better situate these results, we performed complementary analyses comparing participants' speech patterns during different conversation types, accounting for condition, conversation number, speaker, and dyad membership as random effects. In a model predicting turn length with conversation type, argumentative conversations predicted slightly but significantly longer turn lengths compared with affiliative conversations ($\beta = .04$; $p < .005$). Another model predicted total number of speech events in a conversation by both participants using conversation type and found that argumentative conversations had significantly fewer speech events than affiliative conversations ($\beta = -.31$; $p < .0001$).

Multimodal Alignment

Interpersonal Next, we predicted interpersonal multimodal cross-correlation coefficients (r_{multi}) with conversation type and time lag. The main effect for conversation type was again significant, with argumentative conversations predicting a significant drop in r_{multi} ($\beta = -.21$; $p < .0001$). Neither time lag ($\beta = -.02$; $p = .39$) nor the interaction term ($\beta = .01$; $p = .76$) reached significance.

Intrapersonal Our final model predicted intrapersonal multimodal cross-correlation coefficients (r_{self}) with conversation type and time lag. As predicted, we found no significant effect of conversation type on r_{self} ($\beta = .01$; $p = .75$), suggesting that intrapersonal alignment may be less

sensitive to conversation context than interpersonal alignment. Increases in time lag again significantly predicted decreases in r_{self} ($\beta=-.34$; $p<.0001$), suggesting that interlocutors were more likely to be moving when talking and vice-versa. As with unimodal body movement alignment, the significance of time lag as a main effect provided evidence for the existence of in-phase synchrony. The interaction term also reached significance ($\beta=.09$; $p<.05$): Although participants exhibited in-phase multimodal intrapersonal synchrony, individuals' own body movements and speech events were more tightly connected during affiliative conversations.

Network Visualizations of Interaction

To create the network visualizations of interpersonal interaction, we used body movement (M) and speech (S) time series data rather than cross-correlation coefficients. The networks were intended to capture relationships as they occur in time. We created two independent networks, one for affiliative interactions and the other for argumentative interactions (Figure 3). Connection strengths were presented as beta weights obtained through a series of linear mixed-effects models.⁵ All models used condition, conversation number, and dyad as random effects; the intrapersonal models ($M_1:S_1$ and $M_2:S_2$) included participant as an additional random effect. Models used the nodes as predictors of other nodes, according to their connections (e.g., predicting M_1 with M_2).

Discussion

While we often intuitively acknowledge that conversational contexts affect the course of an interaction, our results suggest that there are fundamental differences in interpersonal dynamics during different contexts. During conflict, interpersonal body movement synchrony diminishes. Interlocutors have a more rigid turn-taking structure with fewer and longer turns. Dyads use fewer instances of any overlapping speech, including events like laughter and verbal tracking. Interpersonal multimodal alignment—when one interlocutor is talking and the other is simultaneously moving—drops. Furthermore, in many of these cases, the effect size of conversation type on these measures is quite large, suggesting a very strong impact of context on these aspects of interaction.

On the other hand, some types of behavior exhibit relatively more stable properties across context. Interlocutors multimodally synchronize their own speech and movement, tending to move and speak at the same time regardless of conversational contexts. However, intrapersonal multimodal synchrony can still be affected by context through interaction effects. We believe this reinforces a view of interpersonal interaction as inherently

⁵ The automated speech analysis produces off states frequently, as it prioritizes ignoring non-target speech. This can minimize the magnitude of the negative correlations, since there are frequent off states that match in time during an interaction (e.g., pauses).

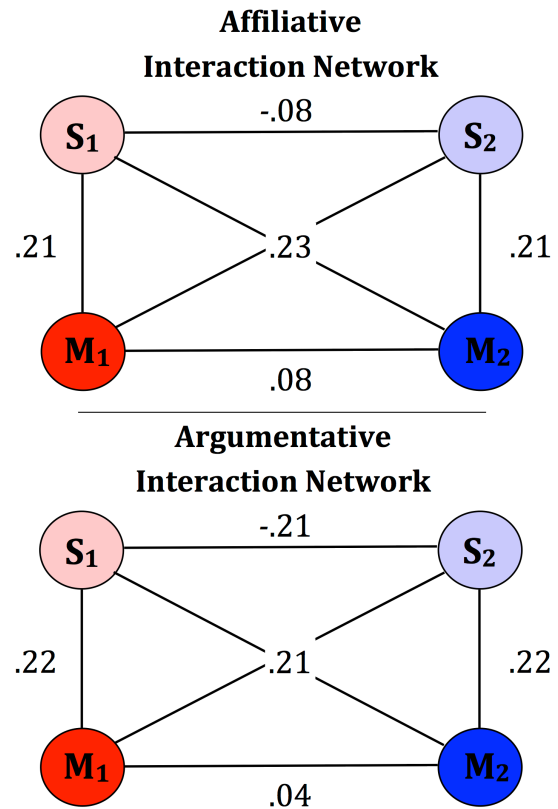


Figure 3: Network visualizations for affiliative (top) and argumentative (bottom) interactions. Colors correspond to those used in Figure 2. Connection strengths are shown as beta weights obtained from a series of linear mixed-effects models and can be interpreted as effect sizes. All connections are significant ($p<.001$).

context-dependent, although the effects may be quite small for some elements or in some contexts.

Our findings paint conversation as a highly complex interpersonal communication structure. While there are some relatively stable elements within it (e.g., intrapersonal multimodal alignment), other elements are very sensitive to conversational contexts (e.g., interpersonal bodily synchrony). While complementary behaviors align across interactions, argument as a conversation context appears to exhibit additional constraints on alignment patterns. Based on these exploratory analyses, interpersonal communicative structures appear to be self-organizing within the interaction and with strong regard to the overall context.

The corpus analyzed here provides a rich source of interaction data in multiple conversational contexts. We intend to continue to mine these data in order to better understand the nature of multimodal communication and interaction and to collect additional corpora on other conversation contexts. In doing so, we hope to more fully develop the interaction network presented here. Future directions will pursue the creation of more predictive models of interpersonal (e.g., Mehler, Lücking, & Weiß, 2010) and intrapersonal (e.g., Tilsen, 2009) multimodal alignment that can shape additional experimental work as

models like the HKB (Haken et al., 1985) have shaped intrapersonal unimodal alignment.

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