18 Social coordination of verbal and nonverbal behaviours

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Interpersonal coordination is key to our everyday experiences. This is apparent in iconic acts of coordination like dancing, but even everyday communication is an intensely coordinative act. From what we say to how we sit, conversation weaves together numerous verbal and nonverbal systems. The diverse behaviours that contribute to communication are distributed across multiple timescales and across physical, cognitive and social systems. The interconnectedness of these systems slips into the background during effortless conversation, but in this chapter we will bring them to the fore. We argue that the interdependence of these systems during communication should be reflected in our study of interpersonal coordination.

We can think of coordination in two related but distinct ways: *coordination as joint action* (e.g. Clark, 1996; Harris, 1996) and *coordination as convergence* (e.g. Giles et al., 1991; Pickering & Garrod, 2004), though further distinctions can be made. Coordination-as-joint-action assumes that two people are intentionally engaged in a common goal, such as cooking a dinner or moving a table, and their actions become aligned and intertwined to reach that goal. In coordination-as-convergence, behaviours become more similar as a consequence of co-presence – like a yawn spreading through a room or romantic partners becoming more similar over time.

In this chapter we will use the term *coordination* to refer to coordination-as-convergence, our primary focus here.[1] Other terms for this phenomenon include adaptation, alignment, mimicry and synchrony, to name but a few (for a review, see Paxton & Dale, 2013c). However, because we will occasionally discuss coordination-as-joint-action, we will point this out to the reader where appropriate.

Coordination is a growing research area that explores the ways that people affect one another over time as a result of their contact. The phenomena and methods are diverse, investigating a range of related questions about emotion (e.g. Neumann & Strack, 2000), posture (e.g. Shockley, Baker, Richardson, & Fowler, 2007) and more. Our chapter reviews empirical work on and extends theoretical explorations of the emergence of interpersonal coordination between verbal and nonverbal systems during interaction. Specifically, we focus on how coordination might occur across various *levels* of communication.

Throughout the chapter we will conceptualize communication systems as constituted by two levels of description or analysis. We will refer to these two levels as *systems*, but we will emphasize that their ontological status is open to continued empirical investigation. *Top-level systems* are relatively *slower* processes that occur on a lower frequency and have fewer degrees of freedom. Examples of top-level systems might include interaction goals, interpersonal relationships and conversational context. *Bottom-level systems*, on the other hand, are relatively *faster* processes, operate on a higher frequency, and have more degrees of freedom available to them. Phonetics, gaze and body movement are examples of these kinds of bottom-level systems.

During conversation, interlocutors balance the needs and pressures of each of these systems. Basic bottom-level demands shape top-level systems, while the top-level constraints feed back into the interaction, moulding the interaction landscape available to the bottom levels (cf. Van Orden, Hollis & Wallot, 2012). To this view, nothing is considered in isolation: all cognitive, physical and social systems are highly interconnected and interdependent during communication. We here investigate interaction as a series of interconnected and interdependent systems, arguing that the bidirectional influence across different levels of communication will provide this domain with a deeper understanding of the integrative aspect of human interaction.

Prominent theories of verbal coordination

Below we highlight four theoretical perspectives on coordination: communication accommodation theory, interactive alignment theory, partner-specific adaptation, and synergies. Though there are many others, these have been perhaps the most influential.

Communication accommodation theory

One of the first accounts of linguistic coordination was *communication accommodation theory* (CAT), also known as *speech accommodation theory*, *accommodation theory*, or *accommodation*. CAT explores the effects of social forces on speech at multiple scales, from speech production to social perception (e.g. Giles, Taylor & Bourhis, 1977; Giles, Coupland & Coupland, 1991; Babel, 2010). One of the defining features of CAT is its focus on the strategic *convergence* and *divergence* of speech behaviours according to social pressures. In this view, individuals are more likely to converge (or engage in similar speech behaviours) when trying to strengthen social ties and are more likely diverge (or engage in dissimilar speech behaviours) when trying to increase social distance (Giles, 1973).

Interactive alignment theory

Pickering and Garrod (2004) proposed the *interactive alignment theory* (IAT) – often known simply as *alignment* – to explain linguistic coordination as largely unintentional. Under IAT, linguistic coordination can be explained primarily through priming rather than conscious choice (e.g. Branigan, Pickering & Cleland, 2000; Ferreira & Bock, 2006). From the seminal work (Pickering & Garrod, 2004), alignment has been targeted as a multi-timescale (e.g. phonetics, diction, syntax) and multi-modality (e.g. speech, cognition) phenomenon in which alignment along one timescale or modality can increase alignment along other dimensions (e.g. Reitter, Moore & Keller, 2006). Perhaps due to this explicit multiscale and multimodal focus, alignment has become a highly influential theory not only for linguistic coordination (e.g. Richardson, Taylor, Snook, Conchie & Bennell, 2014) but also for coordination along a number of other modalities (e.g. Hasson, Ghazanfar, Galantucci, Garrod & Keysers, 2012).

Partner-specific adaptation

Partner-specific adaptation – also known as *talker-specific adaptation* or *adaptation* – advocates for coordination (primarily coordination-as-joint-action) as an intentional process (Brennan & Hanna, 2009). Interlocutors begin communication with a set of shared goals and information called their *common ground*, which grows over time through interaction in a process called *grounding* (e.g. Brennan, Galati, & Kuhlen, 2010; Clark, 1996; Clark & Krych, 2004). As interlocutors increase their common ground, they begin to *adapt* their behaviours to their partner's specific needs (e.g. Brennan, 1991; Rogers, Fay, & Maybery, 2013).

Adaptation is generally most concerned with linguistic communication. In this viewpoint, interlocutors' speech production and comprehension are highly sensitive to one another's needs and understanding. Speakers adapt utterances to facilitate their listeners' understanding through *audience design*, choosing to include or exclude information based on the listeners' needs and their common ground (e.g. Galati & Brennan, 2010; Clark & Krych, 2004). Meanwhile, listeners actively engage in *partner-specific processing* to adapt to speakers' idiosyncrasies and the information available through common ground (e.g. Trude & Brown-Schmidt, 2012).

Synergies

The view of *interpersonal synergies* applies ideas from the motor coordination literature (e.g. Bernstein, 1967; Haken, 1983; Turvey, 1990) to linguistic coordination (e.g. Dale, Fusaroli, Duran, & Richardson, 2013; Riley, Richardson, Shockley, & Ramenzoni, 2011; Schmidt & Richardson, 2008; Shockley, Richardson, & Dale, 2009). This relatively new approach posits that just as muscles in a single body come together to achieve different physical goals, different communicative systems can come together across people to create *synergies* or *coordinative structures*. These structures manage variability in task-relevant domains by reducing the functional degrees of freedom in the system. This facilitates communication by creating on-the-fly groups of systems that are coupled together to achieve interaction goals more easily.

One influential idea emerging from this account is the suggestion that strict synchrony or strong coupling – that is, simply becoming more similar in behaviour and cognition – may not be the most optimal configuration of interpersonal dynamics. Optimality should instead be determined by functional pressures. Therefore, synchronous behaviour across communication systems may be optimal for some types of interactions, while weak coupling or even complementarity across systems may be more optimal for other types of interactions. Recent empirical work supporting this view has centred mostly on synergies within movement (e.g. Black, Riley & McCord, 2007; Schmidt & Richardson, 2008), with an increasing emphasis on interaction (e.g. Abney, Paxton, Dale & Kello, 2015; Fusaroli et al., 2012).

Quantifying verbal coordination

The methodological landscape of verbal coordination research is as rich as its theoretical landscape. Again, we will only introduce a few prominent examples, pointing to in-depth resources for interested readers (cf. Bakeman & Quera, 2011; Kenny, Kashy, & Cook, 2006; Richardson, Dale & Marsh, 2014; Riley & Van Orden, 2005).

Linguistic Inquiry and Word Count (LIWC) and Language Style Matching (LSM)

Linguistic Inquiry and Word Count (LIWC; Pennebaker, Booth & Francis, 2007) is a bag-of-words style text analysis tool that looks beyond word usage to investigate the underlying meaning or style of the text. LIWC scans corpora and categorizes each unit of text (e.g. sentence, paragraph, document) into a number of classes based on default or user-built dictionaries. LIWC provides a context-agnostic evaluation of text composition by percentage that can then be subjected to statistical analysis. While other quantifications of verbal communication may be applied to various types of data, LIWC focuses exclusively on linguistic analyses.

LIWC has been applied to questions of linguistic coordination using large-scale text analysis, from transcripts of face-to-face interactions to large-scale analyses of online data (for review, see Tausczik & Pennebaker, 2010). *Language* (or *linguistic*) *style matching* (LSM) builds on data derived from LIWC to quantify linguistic coordination between individuals, as measured by similarities in usage across LIWC categories. Researchers can use LIWC categories to target more syntactic or structural coordination (e.g. with function words) or broader discourse-level coordination (e.g. with specific content categories), even within the same dataset. LSM measures similar word usage along each LIWC category, allowing researchers to target various levels of linguistic coordination with a frequency-based text-analysis approach.

Distributional analyses

Distributional analyses complement dynamic analyses (described below) by investigating the degree to which statistical properties of behaviours match across individuals over a period of time. Distributional analyses are grounded in the idea that although individuals may differ in behaviour at the local level, interacting individuals should come to display similar frequencies of behaviours during interaction. For example, many bag-of-words analyses do not take into account the fine-grained dynamics of language use but do measure how much interlocutors tend to use similar language across larger chunks of time (see Tausczik & Pennebaker, 2010).

These analyses can be useful for targeting behaviours while abstracting somewhat from time, quantifying longer-scale trends beyond turn-adjacent coordination. For example, various work has investigated verbal coordination through mean speech rate (Webb, 1969) and choices of syntactic construction (Bock, 1986). A subtype of distributional analysis called *complexity matching* (West, Geneston, & Grigolini, 2008) has been used to compare interlocutors' distributions of speech behaviours, showing that individuals tend to produce clustering patterns of speech during interaction (Abney, Paxton, Dale, & Kello, 2014). These kinds of analyses provide a global-level companion to local-level, dynamic analyses of coordination.

Cross-recurrence quantification analysis

Cross-recurrence quantification analysis (CRQA) is an extension of methods originally developed for the natural sciences (Marwan et al., 2007; Marwan, 2008) and is now used to study patterns of coordination over time (for review, see Coco & Dale, 2014). In addition to quantifying temporal patterns of behavioural influence, the method can be used to visualize the interpersonal system in cross-recurrence plots and provide unique insights into recurring patterns of behaviour in the dyad. CRQA can be applied to both continuous and categorical data, providing quantification of coordination in various aspects of verbal (and nonverbal) communication.

Essentially, CRQA quantifies coordination by identifying all possible intersections of identical behaviours between two participants over the course of their interaction. Time series of behaviours (e.g. linguistic contributions) for each participant are recorded. When participants make the same action at the same point in time it is plotted along the $y=x$ diagonal of a recurrence plot, the *line of coincidence*. The two time series are then aligned with a lag of t time points (e.g. milliseconds) between them. Occurrences of the same behaviour are now plotted along $y=x+t$ diagonal. A full recurrence plot consists of all values of t, at whatever granularity is required. Because the cross-recurrence plots include comparisons of *all* possible time points, CRQA allows for the investigation of patterns of influence across long delays instead of simply comparing behaviours as they occurred in time. CRQA can also highlight recurring dyadic states and identify periodic behaviour at the dyadic level.

Multiple resources across various platforms facilitate CRQA. Researchers can turn to the crqa package in R (Coco & Dale, 2014) or the crptoolbox toolbox for MATLAB (Marwan, 2013). The B(eo)W(u)LF data structure (Paxton & Dale, 2013b) can help format linguistic data for CRQA analyses using Python and MATLAB. The computer software Discursis (Angus, Smith & Wiles, 2012) provides a programming-free approach to analysing and visualizing recurrence based on underlying content (i.e. *conceptual recurrence*) instead of lexical choice.

Perhaps the feature of CRQA that makes it so suitable for discussion in this chapter is that it can easily handle both discrete and continuous signals. This means it can accommodate a wide variety of behaviours, creating a common analysis environment in which to explore the dynamics of interdependent behaviours. In the following section we review a series of experiments that feature CRQA as a measure of coordination across verbal and nonverbal systems, highlighting the ways in which different levels and systems constrain and influence one another during communication.

Bridging top- and bottom-level systems: gaze, communication and coordination

Both top- and bottom-level systems have often been studied as distinct entities, perhaps viewed as affecting one another only incidentally. Visual attention provides an excellent example of this. The classic understanding of visual attention holds that it is a veridical information-gathering perceptual system. Its dynamics are determined primarily by features of the world (such as motion and visual contrast) and processes of cognition, such as memory and expectation (e.g. Henderson, 2003). However, this section presents support for an alternative view of visual attention and, by extension, other bottom-level systems: When visual attention is embedded in the *social* world, what emerges is a more complex interplay between interpersonal communication, visual context and the relationship between the people who share it.

For example, one study (Richardson, Dale & Tomlinson, 2009) asked two participants in neighbouring booths to have a political discussion over an intercom while each looked at a blank grid on a computer screen. Despite their lack of shared physical location and their inability to see one another, both partners systematically coordinated their vision during their discussion, looking moment by moment at the same empty regions of the screen. Again, there was *nothing* to see on-screen. In contrast to the traditional views of visual attention, these individuals were not using their eyes to gather information, as there was no information to gather. The only thing moving their eyes was the social context – their interaction and shared common ground.

Additional work supports this same notion: that bottom-level perceptual mechanisms – in this case, visual attention – interact with top-level systems like social context during communication. The studies described next highlight the bidirectional influences that top- and bottom-level systems exert on one another. They exemplify how top-level systems – including beliefs, memory and social context – interact with visual attention, serving as an exemplar for other bottom-level systems (cf. posture in Shockley et al., 2007; overall body movement in Paxton & Dale, 2013a). Taken together, these findings provide compelling evidence for the interconnectedness and interdependence of verbal and nonverbal systems during interaction.

Expectations of context constrain bottom-level systems

We will first look at a case of how even "minimal social context" (von Zimmermann & Richardson, 2014) influences bottom-level systems. That is, when participants simply believe that they are looking at a stimuli at the same time as another individual, it changes how they perceive it – without any interaction taking place between them.

A series of studies (Richardson et al., 2012) asked pairs of participants to look at sets of pictures, some with positive valence and some with negative valence. Half of the time they participants believed that they were looking at the same images as their partner, and half of the time they believed that they were looking at different images. This social context changed randomly on a trial-by-trial basis, and participants reported that they mostly ignored the information about their partner's condition. Despite this reported behaviour, however, simply knowing that another person was attending to the same stimulius – even though they could not see each other or have any verbal interaction – shifted participants' attention. When participants believed that they were looking at the images together with another person, they tended to look towards the more negative images.

In another experiment (also reported in Richardson et al., 2012), participants were told to either (a) search a set of pictures for an "X", or (b) memorize a set of pictures. Each participant was given one of these tasks and was told which of these tasks their partner would be doing as well. In this study we again see the powerful effects that social context and belief can have on lower-level behaviour: Believing their partner was experiencing the same *stimulus* but not sharing the same *task* did not result in joint perception. Joint perception only occurred when participants believed that their partner was engaged in exactly the same task (Richardson et al., 2012). One explanation is that when the stimuli were believed to be shared, participants looked towards the images that they thought their partner would also be looking at. In other words, even with this minimal social context of no interaction, participants were seeking to coordinate their visual attention.

Bottom-level coordination improves cognitive performance

The previous studies on simple expectations of context build on other work that quantifies gaze coordination between people under various conditions. In the following studies the social context becomes richer, as participants are allowed to communicate with each other.

In the first of these quantifications of gaze coordination (Richardson & Dale, 2005), communication is only one-way. The speech and eye movements of one set of participants were recorded as each looked at pictures of TV sitcom cast members and spoke spontaneously about their favourite episode and characters. From these monologues, one-minute segments were cut and played back to a separate set of participants. The listeners looked at the same visual display of the cast members, and their eye movements were also recorded as they listened to the segments of speech. CRQA was used to quantify the degree to which speaker and listener eye positions overlapped at successive time lags. From the moment a speaker looked at a picture, and for the following six seconds, a listener was more likely than chance to be looking at that same picture. The listener was *most* likely to be looking at the same cast member two seconds after the speaker fixated it. The amount of recurrence between the speaker-listener pairs correlated with the listeners' accuracy on comprehension questions that the listeners answered.

A second experiment then showed that gaze coordination and comprehension were causally connected. Pictures flashing in time with the speakers' fixations caused the listeners' eye movements to look more like the speakers', compared to a randomly flashing control condition. This experimental manipulation improved the speed of listeners' performance when answering comprehension questions. This highlights the bidirectional interconnectedness of multiple levels of communicative systems: low-level perceptuo-motor coordination – that is, simply following the gaze patterns of a conversational partner – significantly affects high-level cognitive systems, improving memory and understanding between individuals.

Shared knowledge shapes bottom-level coordination

Conversations are typically interactive, of course. In a study by Richardson, Dale and Kirkham (2007), both participants were able to communicate. They first listened separately to a ninety-second passage describing either the meaning of a specific painting or facts from the painter's biography. Participants then saw the painting together and discussed it while their gaze was tracked. Conversational partners who heard the same information had higher gaze coordination than those who heard different information. These results reinforce the ideas presented earlier from the studies of participants in isolation: Even in completely interactive contexts, higher-level systems – in this case, shared factual knowledge – shape how coordination unfolds in lower-level systems like visual attention.

Concurrent top- and bottom-level coordination

In many of the examples we have reviewed thus far, one system – either the top- or bottom-level system under consideration – has led the other. In Dale et al.'s (2011) gaze coordination experiment, however, coordination emerged from both top- and bottom-level systems, as pairs of participants completed a computerized version of the tangram task (Krauss & Weinheimer, 1964) while being eye-tracked. This task asks each pair to work with a set of six unfamiliar, abstract shapes. Each participant sees the same shapes but arranged in a different order, and each participant is unable to see her partner or her partner's shapes. By talking to each other, the "matcher" must arrange her shapes to match the order of the "director". Once all six shapes are correctly re-ordered, the pair repeats the task.

In the tangram task, a robust pattern of change occurs as the same set of shapes are used repeatedly. Solutions take less time, require fewer words, and are facilitated by a jointly constructed scheme of descriptions for the shapes (Clark & Wilkes-Gibbs, 1986). After multiple rounds the pair is capable of effectively identifying tangrams and completing the task quite rapidly. In this sense, the two people become a coherent, functional unit (Hutchins, 1995).

Another experiment (Dale et al., 2011) showed that during the tangram task the gradual construction of a shared vocabulary – a form of linguistic coordination – filters down to affect the fine-grained dynamics of the partners' eyes and hands, as quantified by CRQA. At the start of the experiment the director's eye movements led the matcher's, demonstrating a lagged but coordinated relation. Intriguingly, this coupling changed over rounds of the tangram task. By the final round, systematic cross-modal coordination emerged: The director and matcher now *synchronized* their gaze and hand movements, with no clear leader or follower. The director and matcher did not simply achieve the task faster; they strongly synchronized their perceptuo-motor activity. With their emerging coordination across multiple top- and bottom-level systems (e.g. linguistic, visual, conceptual), the two participants came to act as a single, coordinated "tangram recognition system" with richly interconnected verbal and nonverbal behaviours.

Putting it together: solving the coordination problem

At the outset of this chapter we argued that language is likely based on a rich process of feedback, and we have presented a series of findings that support this interactivity. Low-level nonverbal systems like motor control and perception weave into longer time scales such as conversations and their topics, which in turn constrain what combinations of actions and perceptions are viable.[2] Guy Van Orden and his colleagues conceived of this process of feedback across time scales as fundamental to the way the cognitive system operates:

> Slower dynamics thus constrain faster dynamics, which allows the flow of visible or audible, or otherwise available, context to constrain the dynamics

> the brain. The flow of invariants across perception occurs on the slower time scales of change in brain activity[…], supplying constraints that reduce the degrees of freedom for what may happen next.
>
> (Van Orden et al., 2012, p. 6)

Van Orden and colleagues intend to describe a relationship between the body or environment and the brain. However, the same kind of relationships can be articulated between fast-changing behaviours in interaction and slower systems like the goals and intentions of our interaction partners. The general idea, from Van Orden and others, is that the system must be integrated in its dynamics for it to function successfully (cf. interaction-dominant dynamics; Van Orden et al., 2003). The implications of this multiscale, multicomponent perspective have not yet been borne out by interaction researchers (cf. Dale et al., 2014).

Simply observing this multiscale and multimodal organization alone cannot "*explain*" interaction. Any theory of interaction must be highly specific if it is to render more compelling mechanistic descriptions and make compelling targeted predictions. Our explanation cannot rest purely on our generic reflections in this chapter. Indeed, most proposals about the computational basis of language – from phonetic cues to syntactic structures – are arguably simpler than the neural makeup of seemingly simple creatures without linguistic communication systems (like, say, squirrels, with brains and bodies that reflect elaborate and impressive engines of evolution).

A concept that may be useful to develop computationally – and dynamically – is that of multimodal synergy. When two people interact they generate a wide array of behaviours. These shape the behaviour of both interacting individuals together. Interaction is thus a coordination problem that is specific to our ecology and that is solved, in our evolution, by placing a wide array of subtle signals in interdependent relationships. In some ways it is astonishing to think that at the surface of one of our most common behaviours is a fundamental scientific mystery: how do we solve this coordination problem? We are solving synergies not only among muscle groups (Bernstein, 1967; Turvey, 1990) but also at interrelated time scales that, importantly, must fluidly interact to get the system right.

We believe an important next step will be using network formalisms to understand these patterns of interdependence. They can be devised concretely and without strong representational commitments, while allowing researchers to be explicit about relationships among levels. These networks can have the sophistication to capture synergies (Sporns & Edelman, 1993) and perhaps even tensegrities that could be vital to understanding perception and action (Turvey & Carello, 2011). Such an approach, while risking certain theoretical assumptions or ontological simplifications, would permit explorations of multilevel relationships. Recent work on deep learning neural networks, for example, would allow exploration of behavioural modes at different spatial or temporal levels (Hinton et al., 2012). We have already conducted some initial discussion and visualization in terms of networks (see Figure 18.1; see also Bergmann & Kopp,

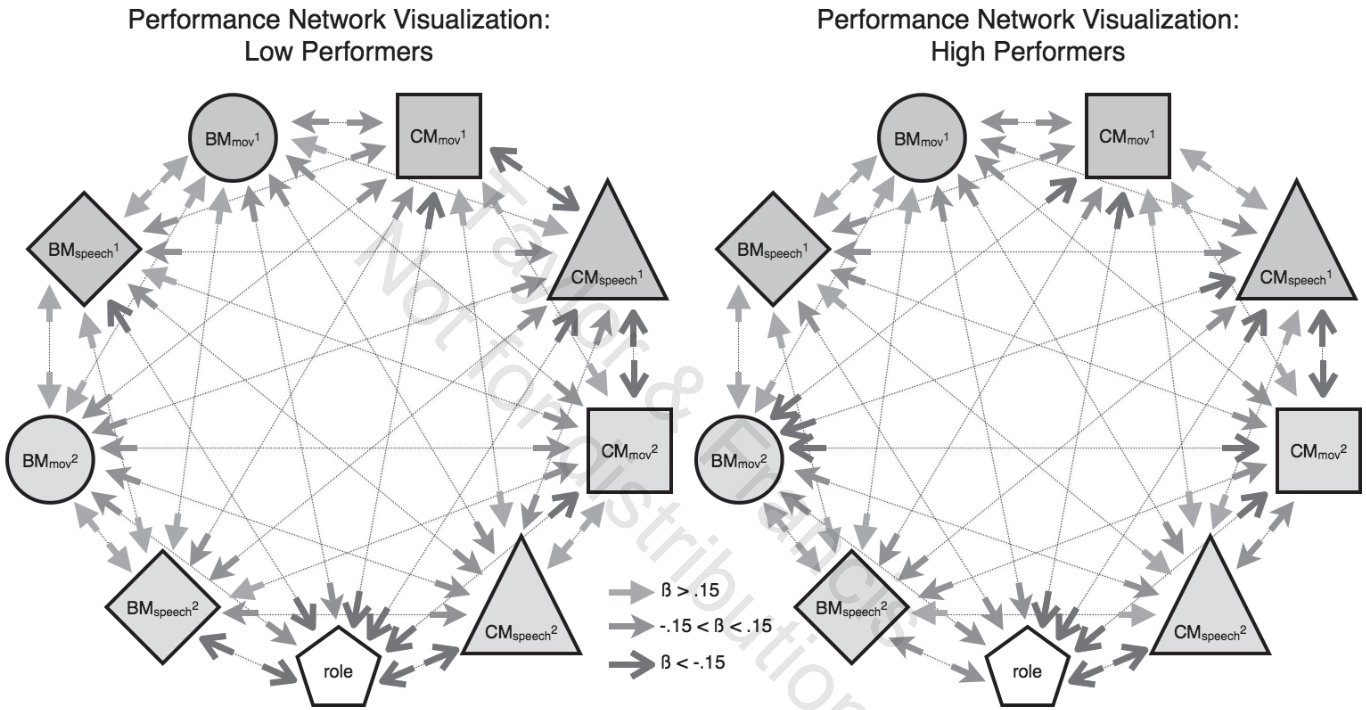

Figure 18.1 Network visualization of top- and bottom-level communication systems during a cooperative dyadic task (Paxton et al., 2014).

Network analyses, visualizations and models can spur new insights into the relations across top- and bottom-level systems – for instance, by seeing how the connections between various systems change according to the performance on a cooperative task. (In this figure: BM = behaviour matching of speech [subscript *speech*] and movement [subscript *mov*]; CM = complexity matching of speech [subscript *speech*] and movement [subscript *mov*]; role = beliefs about distribution of power during task; superscript numbers = first or second half of the task.)

2010; Dale et al., 2014; Dale & Louwerse, 2012; Paxton, Abney, Dale & Kello, 2014). These initial forays offer a glimpse at what may be possible in the future: a more *integrative* understanding of the function and structure of human interaction.

Conclusion

The recent explosion of interest in coordination has led to a host of new and interesting questions about verbal and nonverbal communication. The goal of this chapter has been to act as a guide to theories and analyses of verbal coordination to ground this new interest in the history of investigations into how and why individuals affect one another's communicative behaviours. These theories and methods serve as an important foundation for exciting new ways of seeing verbal coordination, viewing the verbal systems as simply *part* of a larger network of communication systems. Seeing each of these systems as interconnected leads to a richer – and, arguably, more situated – picture of communication and coordination.

As we have noted throughout this chapter, however, this line of research is far from complete. Additional research must continue to map out this interconnectivity across levels of communication. These new questions extend old lines of enquiry, bridging traditionally distinct research areas to more fully understand the complex interactions across multimodal, multi-timescale levels of communication.

Notes

1 Of course, convincing arguments can be made to include many of the phenomena discussed here as coordination-as-joint-action, but these are outside the scope of the current chapter.
2 We thank an anonymous reviewer for pointing out the similarity between this view and the *enslaving principle* from synergetics (e.g. Haken, 1983).

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