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Alignment, Transactive Memory, and Collective Cognitive Systems

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Abstract Research on linguistic interaction suggests that two or more individuals can sometimes form adaptive and cohesive systems. We describe an "alignment system" as a loosely interconnected set of cognitive processes that facilitate social interactions. As a dynamic, multi-component system, it is responsive to higher-level cognitive states such as shared beliefs and intentions (those involving collective intentionality) but can also give rise to such shared cognitive states via bottom-up processes. As an example of putative group cognition we turn to transactive memory and suggest how further research on alignment in these cases might reveal how such systems can be genuinely described as cognitive. Finally, we address a prominent critique of collective cognitive systems, arguing that there is much empirical and explanatory benefit to be gained from considering the possibility of group cognitive systems, especially in the context of small-group human interaction.

Active externalism refers to the view that features of an individual's environment, with which the individual is continually engaged in an ongoing interaction, are as much a part of cognition as are other parts of the human brain. Cellular phones and personal computers, for instance, are artifacts which individuals use in their cognitive endeavors on a regular basis. According to active externalism, the interaction between these artifacts and the individual constitutes a *coupled system* that functions as a cognitive system in its own right.

Although early attempts to defend active externalism focused on coupled systems that involve a single individual and an artifact (Clark and Chalmers 1998), the possibility and plausibility of group cognitive systems—systems involving multiple cognitive agents that are systematically integrated—are now the subject of a rapidly growing body of literature (Hutchins 1995; Giere 2006; Giere and Moffatt 2003;

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Theiner and O'Connor 2010; Wilson 2004; including the extensive collection of reviews in Kirshner and Whitson 1997; Salomon 1993; Payette and Hardy-Vallée 2008; and the well-established fields of *Computer-Supported Cooperative Work* and *Computer-Supported Collaborative Learning*, both the subjects of entire conferences, are inspired by this line of thinking). Our aim in this paper is to bring research on alignment in linguistic and interpersonal interaction to bear on the debate regarding group cognition. In particular, we argue that empirical research on alignment in human interaction lends plausibility to the idea that groups of people can achieve the cognitive integration needed to form adaptive systems in the manner described by Rupert (2011).

In section I, we begin with a discussion of the empirical research on alignment in conversation and interpersonal interaction. Ongoing research on linguistic interaction suggests that two or more individuals can sometimes form adaptive and cohesive systems. In particular, the lower-level processes involved in linguistic interaction seem to provide a bedrock by which individuals achieve and sustain cognitive coupling. In section II, we describe what we have called elsewhere (Tollefsen and Dale 2012) an alignment system—a loosely interconnected set of cognitive processes that have evolved to facilitate social interactions. As a dynamic, multi-component system, it is responsive to higher-level cognitive states such as shared beliefs and intentions (those involving collective intentionality) but can also give rise to such shared cognitive states via bottom-up processes ("emergent": Knoblich et al. 2011). Through processes of alignment participants in social interactions (such as conversation and joint action) become increasingly coupled, integrating subjects along multiple levels of cognition. As an example of putative group cognition we turn to transactive memory and suggest how further research on alignment in these cases might reveal how such systems can be genuinely described as cognitive. In section III, we address concerns that might head this research program off at the pass by considering and responding to Rupert's (2011) recent criticisms of group cognition.

1 Alignment Research

Alignment refers to the dynamic "matching" between the behavioral or cognitive states of two or more people over time. Gestures, eye gaze, word choice, and various other behavioral features may become coordinated in human interaction. For example, two people observing a work of art may come to closely match in their eye movements, especially if they understand each other well (e.g., Richardson and Dale 2005; Richardson et al. 2007a). Also, two individuals may seek to compensate for their observed differences by more closely moving their bodies in synchrony (e.g., Miles et al. 2011). This process essentially involves continual mutual adaptation. Alignment should be distinguished from mere mimicry. As Richardson et al. (2005) note, mimicry refers to a simple matching of behavior. It is essentially a "one off" behavior and is often asymmetrical or one-way (consider, for instance, the facial mimicry of neonates: Meltzoff and Moore 1977). Mimicry does not essentially involve a coupling of cognitive agents. Alignment, on the other hand, is a coordination of behavior across time and is achieved through mutual responsiveness. Here we use "alignment" as a generic term for such real-time coordination, and there are many terminological variants with subtle connotations: entrainment, coupling, synchrony, and so on. The behaviors that become entrained may match but they need not. Dancers, for instance, perform different but complementary actions. In a successful performance, their different movements are synchronized and mutually adaptive. The synchronizing of different behaviors across time and in response to changes within and external to the coupled system is characteristic of alignment as we conceive of it.[1]

Although we conceive of alignment as distinct from mimicry, our capacity to form coupled systems likely relies on the basic ability to mimic the behaviors of others. Low-level mimicry and basic priming mechanisms that may generate mimicry probably help to start and sustain mutual adaptiveness (Tollefsen and Dale 2012). What we wish to highlight is that the integration of these low-level processes, contextual variables, high-level cognitive plans, and so on, sustains a robust pattern of interaction between human beings when they interact. A mere glance at the literature on interpersonal interaction reveals this adaptiveness.

Several studies have demonstrated that the emerging sub-personal processes supporting conversation are ones of *alignment* (Pickering and Garrod 2004; Garrod and Pickering 2004). Shockley et al. (2003) have shown that body posture aligns during naturalistic conversation, potentially generated by subtle matching of verbal cues (Shockley et al. 2007), which also align during interaction (Giles et al. 1991; see also Chartrand and Bargh 1999). Beyond such low-level bodily alignment, Pickering and Garrod (2004) also maintain that the joint activity of conversation succeeds most fluidly when representations and processes align across various levels of linguistic organization, from words to choice of sentence structure (e.g., passive vs. active voice; Bock 1986; Branigan et al. 2000). In addition, priming theories of alignment (Pickering and Garrod 2004) have proposed that cognitive accessibility of certain behaviors (e.g., a chosen sentence structure) is induced by hearing another person use it, thus increasing the likelihood of one's producing a related behavior. This alignment by priming predicts a gradual unfolding of shared states between two people exchanging information. It appears that conversants exhibit alignment even at the highest levels of linguistic organization, such as strategic use of irony or sarcasm (Roche et al. 2012).

As such alignment processes unfold during an interaction, multimodal channels of behavioral activity also align. As just noted, this may be the case with posture (Shockley et al. 2003) and other rhythmic behaviors (e.g., Richardson et al. 2007b), but other systems also exhibit this alignment. Richardson et al. (2007b) have demonstrated that there is a tight coupling of visual attention during conversational interaction. As people discuss a work of art, their eye movements become distinctly aligned in time. Indeed, it seems that the better the alignment, the better the participants understand each other – or, in other words, the better they succeed in fulfilling the shared goal or intention of communicating with one another (Richardson and Dale 2005). These low-level processes unfold alongside general adaptiveness to a conversation partner's needs, such as their understanding of the task or their lack of familiarity with one another (see Brennan et al. 2010; Brown-Schmidt 2009;

[1] In psycholinguistics, "alignment" has recently been used as a specialized term for the emerging sameness of linguistic representations (e.g., Pickering and Garrod 2004). We use it here in a more generic sense of systems temporally coordinating their behavior, whether the same or not.

Brown-Schmidt et al. 2008; Schober and Brennan 2003). This research highlights the connections between linguistic alignment in conversation (e.g., syntactic, semantic) and behavioral alignment (e.g., posture, eye gaze). Behavioral alignment seems to give rise to alignment in conversation, which, in turn, gives rise to a mutual understanding and a deeper understanding of one another, which amounts to an alignment of overall interactive comprehension. It doesn't happen all the time (see Shintel and Keysar 2009, for review), but it happens robustly in many interactive contexts. Recent research has sought to identify such robust conditions, such as in the congruence of goals among group members (e.g., Ondobaka et al. 2012).

These are not simply “boutique” findings, where tasks are, by their design, engendering mutual adaptation. A recent study has shown that this synchrony holds across a host of these behavioral channels simultaneously during a single naturalistic interaction (Louwerse et al. 2013) and that it correlates with task-related performance variables. In this study, the researchers video- and audio-recorded two people interacting while one directed another in a navigational task. Videos were coded for communicative behaviors across dozens of dimensions spanning a range of complexity, from low-level facial expressions (e.g., furrowing the eyebrows, smiling) to high-level linguistic contexts (e.g., explanation, asking questions). The researchers found that, on average, partners exhibited systematic temporal alignment across many of the channels. In addition, the extent of that alignment predicted how long they had been interacting (i.e., the longer the interaction, the higher the alignment) and task difficulty (i.e., the more difficult the directions, the higher the alignment). Put simply, the human interactive system becomes a more tightly coupled multichannel system as time goes on, potentially adapting over time and in the face of challenges.

The most recent empirical studies cited above are from cognitive psychology, and they complement a rich history of research on alignment in other areas of psychology. Research on “mutual adaptation” in social psychology has examined a wide variety of adaptive behaviors including, speech rate (Street 1984), speech accents (Giles and Powesland 1975), postural and gestural behaviors (Maurer and Tindall 1983), and head nods and facial affect (Hale and Burgoon 1984). More recent research suggests that aligning with others hones the perceptual and motor skills necessary for successful collaborative endeavors. It has long been established that synchronized movements (e.g., marching, dancing) enhance rapport and pro-social behavior (Bernieri 1988; Miles et al. 2009), but more recent research suggests that when synchronizing with others, in tasks such as dancing and marching, it will improve perceptual and motor ability during cooperative tasks. The effect of synchronizing one’s body with others across time appears to be one of tuning basic cognitive process (Valdesolo et al. 2010), which facilitates social interactions (Hove and Risen 2009).[2]

Two people interacting may also engage in complementary alignment, as well (see, e.g., Fusaroli et al. 2012). In this case, it is important for one person to choose a

[2] The basis for alignment might be found in more basic neural mechanisms. For example, the presence of a mirror neuron system in humans has obtained some empirical support (Rizzolatti and Craighero 2004) and may be the basis for shared understanding of actions across two people observing each other (and consequences of actions; Bekkering et al. 2009). This substrate could partly underlie our capacity to map our own actions onto the observation and understanding of others’ actions by employing overlapping neural hardware. It may be that this connection between two people’s actions and representations can produce interpersonal influences that shape even basic cognitive response processes (Sebanz et al. 2003).

particular behavior that complements, rather than matches, that of their partner. Imagine the following scenario: You are helping a friend unload from a truck. There are a variety of objects that need moving, from small boxes to large tables or shelves. It is likely the case that you and a friend could easily move a large table, without too much negotiation, by taking a particular side, orienting appropriately, and moving your body in a completely complementary manner (e.g., left leg forward vs. right leg forward). This spontaneous *complementary* perceptuomotor alignment is precisely what Richardson et al. (2007b) found in a study of participants who had to move objects from one location to another in the laboratory. When objects achieved a particular size, participants spontaneously organized themselves into a complementary perceptuomotor unit, and moved the object together. What Richardson et al. (2007b) found was that this boundary—the point at which "joint" moving occurred—was very similar to the individual case, where a single person decides when to use one hand or two to pick something up; that is, the joint action dynamics resemble, in detailed mathematical ways, the interlimb dynamics of a single person.

Two people can form a coupled unit even when engaged in substantially different behaviors. For example, Ramenzoni et al. (2012) show that when two people are coupled through a precision task activity, the complexity of their performance is lower when they are performing it cooperatively. In other words, they come to form a complementary but coherent "perception-action" system. Some recent work on social interaction in a task context shows that performance is increased during both *selective* alignment and *complementary* patterns of linguistic behavior (Fusaroli et al. 2012). Additionally, some work has begun to articulate this process occurring at the level of the brain, by identifying patterns of coupling quantifiable in fMRI and other signals during interactive tasks (see Hasson et al. 2012).

It is important to note that cognitive and behavioral alignment is something that often occurs unintentionally. Participants in these studies do not aim to align syntactically or semantically, nor are their bodily alignments intended. They are often unaware that they have become cognitively and behaviorally entrained. The processes involved in alignment can be – perhaps, even, for the most part – at a very low level. For example, minimalist accounts of this alignment would argue that subtle cues in the interaction coupled with very basic sub-personal processes can bring about systematic social behavior (e.g., Shintel and Keysar 2009; Barr 2004). This suggests that many social interactions (and specifically joint actions) could be fueled largely by bottom-up processes rather than top-down (higher-order) cognitive processes such as shared intentions and explicit agreements. In fact, there is vibrant debate in this domain about the mechanisms of social interaction (e.g., Brennan and Hanna 2009; Shintel and Keysar 2009).

2 The Alignment System and Transactive Memory

As reviewed in the previous section, there is considerable evidence that participants become rapidly behaviorally entrained along a variety of dimensions while engaging in joint tasks like conversation. We have identified these various dimensions and the dynamic relationships between them as forming the basis of an alignment system (Tollefsen and Dale 2012). This alignment system is a "system" in the sense that it is a loosely interconnected set of cognitive processes that have evolved to facilitate social interactions and joint actions, in particular. If all these processes are working during social interactions, the alignment system is a heterogeneous mix of components entraining two or more people to specific patterns of behavior. It is important to note that most of the components making up this system are likely to be relatively low level in nature.[3]

The role of priming and mimicry discussed above needs only the accessibility of particular mental states to become aligned during, for example, conversation. This can happen entirely unconsciously without the involvement of explicit commitments or agreements. In addition, if the components are to function in the right way, they should mutually constrain each other in a manner that is sometimes termed *synergistic*. This means that the components of the system act as one coordinated body, in the sense that the overall behavior can be described using an emergent and lower number of dimensions than the high number of processes and components themselves. Variants of this definition have been identified by some researchers who have recently found that two-person systems organize in this way (see, e.g., Konvalinka and Roepstorff 2012; Richardson et al. 2007b; Ramenzoni et al. 2012; Riley et al. 2011).

The behavior of this system can be therefore understood in terms of the framework of self-organizing dynamical systems (for recent thorough review see Richardson et al. 2013). Researchers in this tradition have used the concept of "coordinative structure" to explain how a large number of degrees of freedom (e.g., in muscle groups) are not centrally controlled but rather self-organized into coherent, functional units (e.g., dancing the jig vs. throwing a baseball). The problem is one of reducing degrees of freedom through mutual constraint among parts of the body. In a similar fashion, it may be that social interactions and joint tasks induce gradual mutual constraint across two or more people's bodily and cognitive states. By this account, joint activity is an emergent, self-organizing phenomenon produced through "coordinative structures" of two or more people (Shockley et al. 2009).

Until this point, we have discussed alignment and the alignment system as it functions in social interaction and have pointed to research on linguistic and behavioral alignment that seems to support the view that dyads and small groups can form a cohesive unit. But does alignment contribute to the formation of a single unit of *cognition*? Joint activity might be an emergent, self-organizing phenomenon, but is it group cognition?

In order to answer this question we turn to consider a paradigm case of cognition: memory. Because memory subsumes virtually all other cognitive processes it behooves those who want to argue for group cognition to focus on it. In "transactive memory," one individual's memory is shown to function alongside that of another person or persons, as a kind of socially extended memory system (e.g., Wegner 1987). Classic examples of transactive memory systems are married couples that may either have a division of epistemological labor (Wegner et al. 1985) or rely on each other for dynamic cuing of episodic memories (Hollingshead and Brandon 2003). A transactive memory system involves the complex interaction of individual

[3] For example, the mirror neuron system may directly map perceived actions to one's own potential action execution, a rapid blend of self- and other- that needs no high-level processes.

memory systems. These individual memory systems are not merely external storage devices, because both the process of remembering and storage of memories is often done in an interactive and dialogical manner. Unlike a notebook which does not itself have the characteristic of memory identified by mainstream memory research (learning time and access time)[4] a group of individual memory systems can, it seems, become unified and produce a memory product (recall an event, say) that is richer than that recalled by an individual. Consider the case of an academic department's subcommittee charged with revising the department's policies and procedures. Faculty member A might offer some information that he remembers about the history of the department, faculty member B might offer information about what the department chair requires of the committee, faculty member C might remember something said by the Provost regarding policy making. As a result the committee might recall a great deal more information relevant to their task than any individual alone and we can imagine that such recall is done in a collaborative and dialogical process. Importantly, the outcome is also not merely *summative*; the combination of these sources of information may radically alter the decisions to be made. Information may have been stored in individual minds or heads but the retrieval was done through conversation.

Transactive memory systems as described by Wegner go through the same stages that occur at the individual level: encoding, storage, and retrieval. Encoding at the collective level occurs when members discuss information and determine the location and form in which it will be stored within the group. Retrieval involves identification of the location of the information. Retrieval is transactive when the person holding an item internally is not the person who asked to retrieve it. In our case above, a faculty member may have promoted retrieval of information from another faculty member by asking questions and offering alternative hypotheses that the committee member needed to consider.

Individuals in a transactive memory system generally know something about each other's domains of expertise and storage capabilities.[5] Known experts in the group are held responsible for the encoding, storage, and retrieval of domain-specific information. Other members contribute to the storage of information by directing new information to the appropriate expert. When there are no clear experts other ways of assigning responsibility for the information are used: For example, the person who first introduces the information may, by default, be held responsible for processing that new information. Communication may be crucial to these memory systems, as such systems are formed through a process of interaction over time (Hollingshead and Brandon 2003). Individuals must, perhaps initially, participate linguistically in transacting collections of information. They must be involved in the allocation of information to specific experts, for instance, and in the determination of what information will be stored.

[4] An article by Robert Rupert (2004) argues the extended mind hypothesis is wrong to think of external aids (notebook) as part of the cognitive system because external memory differs radically from internal memory. We don't think those objections apply to the case of transactive memory as the transactive memory system is meshing of individual memory systems traditionally conceived of. See Tollefsen (2006) for a similar response to worries about memory and collective cognition.

[5] As one reviewer rightly notes this knowledge might be tacit. They might simply have a "sensitivity" to others epistemological and cognitive domains.

As Barnier et al. (2008; Barnier and Sutton 2008) note, until recently, the results of transactive memory research have been limited, both in methods and results. The limited results suggest that people in long-term relationships (particularly intimate relationships) perform better on categorized memory tasks than pairs of strangers (Wegner et al. 1991) when the "intimate" pairs are allowed to use their own ways of learning material rather than an imposed structure (Hollingshead 1998).[6] Such research focuses on the benefits of remembering together and is based on a paradigm that involves individuals memorizing a list of items together and comparing the recall on those items with the recall of items memorized alone. More recent research by Sutton et al. (2010) suggests that adopting a more ecological approach yields more significant results. Intimate couples who are allowed to participate in a joint remembering through conversation seem to produce a mnemonic product that is richer than any individual memory (Harris et al. 2011). In addition, by appealing to research on transactive memory systems in the context of small task groups (Liang, Moreland, & Argote 1995; Lewis 2003), Theiner (2009) has argued persuasively for the existence of emergent cognitive properties of these systems.

Because transactive memory involves conversation both in the storage and retrieval stage, we believe research on alignment at syntactic, semantic, and perceptual levels will provide evidence that we are dealing with collective cognitive systems. Researchers are likely to see the same sort of synergy, described above, in the conversational context. We can think of alignment in these contexts as the cognitive glue that binds participants together in a cognitive endeavor such as remembering. The alignment system we described above will, we propose, have a large role to play in transactive memory. We might then appeal to systems theory in order to understand the emergent properties and products that result. And such a system seems a promising candidate as having cognitive status, as memory is a paradigm case of cognition.

Alignment at the syntactic, semantic, and perceptual level will, as it does in conversation, produce cues that support and sustain the interactions involved in the transactive memory system. When known partners are brought together in transactive memory experiments they bring with them patterns of alignment at various levels. Their pre-established entrainment will significantly affect the transactive memory system. During storage of information, for example, participants' coordination and alignment of eye gaze patterns will have a significant effect on the types of information stored and the cues tied to that information (Richardson and Spivey 2000; Richardson and Dale 2005). Too much alignment, for instance, might be deleterious for the transactive system as it limits the scope of information held by the system (see also Fusaroli et al. 2012; Wu and Keysar 2007). Because transactive memory forms a distributed system, alignment might interfere with that distribution. But at the same time, alignment at the lower level might provide shared cues that then facilitate the retrieval process (see discussion in Louwerse et al. 2013). This would be particularly so during collaborative learning, as opposed to the individual learning employed in much previous research.

[6] Incidentally, it occurs to us that it may not be the best way to test the existence of a system by whether it performs better or worse than some other system; the question is whether two people *indeed act* as a transactive system, and this seems to be separate from whether they are performing well.

Alignment research could fruitfully augment research on transactive memory research and collective remembering in a variety of ways. Do groups that interact over time, sharing and discussing their memories, become more behaviorally and cognitively aligned? If so, what is the effect of alignment on subsequent recall? What are the dynamics involved? Does the sharing of significant memories cause alignment at the level of cognitive representations that in turn influences alignment processes at the lower level? If encoding contexts and recall cues are shared between two people, they may serve as a coupled feedback system, strengthening access to cues and thus pieces of relevant information to be recalled (see, for example, Richardson and Spivey 2000). Put simply, integrating alignment system work and transactive memory research may reveal the mechanisms by which two or more people become coupled to form a cognitive system.

Our discussion here remains tentative. The role our alignment system plays in transactive memory will have to be determined by empirical research. Our aim here is two fold: to lay out a research project that will uncover the mechanisms involved in transactive memory, and to lend support to the view that groups or dyads can form genuine cognitive systems.

3 Skepticism About Group Cognitive Systems

A few clarifications are in order before we consider one of the most compelling arguments against group cognitive systems. First, let's begin by identifying the sort of groups we think are plausible candidates for cognitive systems. Discussions of group mental states and attitudes usually focus on large structured groups such as organizations and corporations (e.g., Huebner 2008; Knobe and Prinz 2008). We think the most promising line of research on group cognition will focus on small task groups, teams, and dyads that are working together on a sustained basis, such as in conversation and collaboration. Smaller groups involving multiple agents will have clear lines of interaction and patterns of alignment that will form the basis of the coordinative structures that compose a group cognitive system. Second, although at least one of the authors of the present paper has argued that organizations and corporations can plausibly be interpreted as having mental states, we have not here argued for group mental states. Rather, we are suggesting that our alignment system can explain how agents can be cognitively integrated in a way that makes viewing them as a single cognitive unit *plausible* and *explanatorily fruitful*. Finally, and importantly, we would not contend that all cases of conversation or collaboration involve group cognitive systems. We would instead argue that some such activities may qualify by having important dynamic alignment properties. When conversations bring about the cognitive operations of a robust social transactive memory system, we may have one such example.

In *Cognitive Systems and Extended Cognition* (2009) and in more recent articles (e.g., Rupert 2011), Rupert defines a cognitive state in terms of its role in a larger system. A state is cognitive if it functions within a cognitive system, where a cognitive system involves various mechanisms and processes that "contribute causally to the production of a wide range of cognitive phenomena, across a variety of conditions, working together in an overlapping way with a variety of other mechanisms of similar standing" (2009, p 41).

Cognitive systems are persistent and display a set of capacities that persist across different contexts. This persistence is best explained, according to Rupert, by the fact that they are realized in a physically bounded organism:

> …there is a natural explanation of the persistence of the relevant capacities; they are physically realized, and the persisting organism provides their integrated, physical substrate; the organism as an integrated physical entity appears in the various circumstances of interest, and its persistence explains the persistent appearance of the integrated set of cognitive capacities realized by the organism. (2009, p. 40)

This systems-based approach is then used by Rupert to rule out (or at least cast serious doubt on) artifacts like cellphones or calculators as part of the cognitive system and activities involving these artifacts as cognitive processes, because such things are not integrated in the ways that, say, vision, linguistic processes, and short-term memory are typically integrated. We may depend on a notebook for address information, but this resource shouldn't count as cognitive because it is not part of the integrated system.

We are not convinced that the conditions for an integrated system could not be met by the sorts of small task groups we are considering, particularly those that work together over time.[7] There are many ways in which "integration" could be defined. The physical integration that Rupert describes in fact holds in tightly knit small groups (after all, perceptuomotor connections are a fact of physical reality: Turvey 2007). For example, consider the conversational case again. Evidence from experimental data supports the view of *some dyads* as a single system. Figure 1 represents data taken from a naturalistic conversational task, in which dyads were inconspicuously filmed during a self-guided conversation about media that both individuals enjoyed (Paxton and Dale 2013). Movement data were extracted from the video using a frame-differencing method that registers movement as changes in pixels across frames, and participants' individual speech streams were preserved using lapel microphones on separate audio channels. The data presented in Fig. 1 were collected from a dyad of previously unacquainted female undergraduates for a subset of their 10-minute conversation.

Figure 1 demonstrates the complementary alignment of the interlocutors' speech and body movement (one person in light grey, the other dark grey). The solid lines

[7] It is worth noting here that one of the objections that Rupert has raised in the past (2004) to extending the boundaries of the mind, have focused on the role of memory in conversation. According to Rupert, external memory aids such as notebooks should not count as memory because we don't use them in the way that we use working memory in the context of conversation and if we did it would be an odd and painful conversation. We think he is right about this. Tollefsen (2006) has argued that the extended mind hypothesis is much more plausible when it comes to social coupled systems (involving other cognitive agents) than when it simply involves artifacts. Our alignment system and the research on alignment in conversations suggest that we were built to couple with others cognitively and not with artifacts like notebooks. The synergy, mutual adaptation, and on going interaction that is required for systems is more plausibly found in transactive memory systems than between Otto and his notebook.

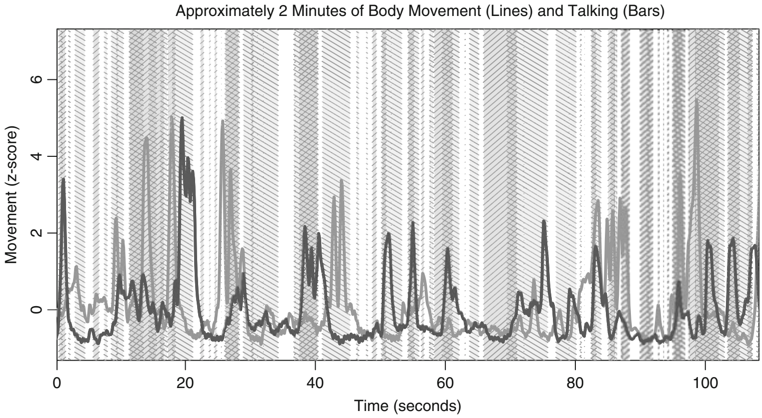

Fig. 1 Body movement and speech state of a dyad engaged in conversation for about 2 min. One person's data is shown as light grey, the other's as dark grey. The intensity of body movement is represented on the y-axis, and shown in lines (see Paxton and Dale 2013, for description of this scale). Moments of speaking are represented in hatched and shaded vertical bars. Overlapping speech appears as cross-hatching

track the interlocutors' body movement over time, with higher magnitudes of body movement as higher peaks in the dark and light grey lines. The hatched and shaded boxes on the figure represent the corresponding speech events, with cross-hatched boxes designating overlapping speech events. The strength of their interpersonal alignment is also evidenced through their individual body movement time series (graphed as lines), which tracks overall body movement through pixel changes in video recordings over time (for further detail, see Paxton and Dale 2013). The immediacy of their turn-taking structure is impressive: At times, the interlocutors' turns are timed such that one begins speaking just as the other ends, so that their individual speech is almost indistinguishable from one another (see also Stivers et al. 2009). In addition to some periods of relatively independent movement (e.g., one participant moving while the other participant is relatively unmoving), there are distinct patterns of bodily alignment—and even periods during which the patterns of body movement appear highly similar in variation (e.g., both participants demonstrating similar magnitudes of body movement). To us, this seems like an adequate substrate for physical integration. Other possible physical patterns of connectivity can also be identified, such as multichannel synchrony (Louwerse et al. 2013), pink-noise signatures holding between two interacting persons (akin to the artifact case: Dotov et al. 2010), and a reduced quantitative complexity in the behavior of *two* vs. *one* person (see Ramenzoni et al. 2012; Riley et al. 2011).

A second issue is that the physical integration (systems-level neuroscience) Rupert favors, while certainly central, is only part of the story: The encapsulated brain in fact engages in extensive transactions with the peripheral nervous system, and both rely on feedback loops with the external world to preserve our sense of cause and effect, will, time perception, and so on (Jeannerod 2006). Cognitive science should be free to consider the possibilities that small groups—adaptive perceptuomotor couplings and information exchanges—"give off" cognitive indices just the way an individual human does. It is true that small groups can more readily dissolve than a single brain, but this seems to be an interesting fact about the integration of people, rather than a criterion that discounts their "cognitive-like" integration. After all, brains can get injured, operated upon, and die; small groups may also have identifiable forces that determine their dissolution (e.g., Albert and Kessler 1978).

The individual level is obviously involved in understanding group-level behavior; however, the group behavior cannot be reduced to the individual level alone but must also include the interaction among the elements of the individual level. One requires a non-individual mechanism to do so: the manner and distribution of inter-individual interaction. Put differently, if one is seeking to understand conversation or collaboration, the explanation will seek generalizations "above" the individual—laws or statistical regularities that describe the individuals' interaction with one another. The group mind proposal, in the softer "big tent" mode, proposes that notions of individual cognition (e.g., computation, parallel processing, or any other flavor one might choose) would be useful to explaining these emergent, inter-individual processes. The idea of elaborating on inter-individual and individual-technology interactions—as a subject of analysis itself—is part of broad domains referred to as *Computer-Supported Collaborative Learning* and *Computer-Supported Cooperative Work*. These fields appear to assume that the interactions among persons and their technologies necessarily give way to new and potentially unintuitive facts and that collaborative and learning systems are valid levels of analysis unto themselves (see Grudin 1994, and Neale et al. 2004).

In addition to the notion of integration, Rupert (2011) emphasizes that cognition requires an architecture and that this view is common across all theoretical camps in cognitive science. If "architecture" simply means an implemented model of specific parts, this seems inarguable. However, it seems that most computational mechanisms implemented in models of cognitive science can be similarly implemented for the purpose of exploring groups. For example, dynamical systems are often used to characterize interpersonal interaction (e.g., Schmidt and O'Brien 1998), Bayesian processes can model how generations of people accumulate linguistic change (e.g., Griffiths and Kalish 2007), and the parallel-processing of a neural network model can also be used to capture the interaction among members of a group (e.g., Vallacher and Nowak 1994). In fact there are several domains of computer science that articulate what are traditionally deemed "cognitive mechanisms" but implemented by groups of agents acting in concert (e.g., see swarm optimization: Kennedy and Eberhart 1997; see also collective intelligence and crowdsourcing examples: Halpin et al. 2007). The idea of group-level "cognitive architectures," inspired by the individual case, is already present in some literatures. When we model a group using neural networks or dynamical systems the assumption is that collective group activities have regularities that resemble, in some way, the activities of an individual who may also be modeled with these architectures. Discounting the cognitive possibilities here, simply because they are not encased in a cranium, seems to be obscuring progress in understanding how they function as a genuine system of some gradient stability.

4 Conclusion

In this paper we have attempted to move research on collective cognitive systems forward by introducing the empirical research on alignment and suggesting that an alignment system can provide the sort of integration necessary for cognitive systems. We have focused on the case of transactive memory—as a putative cases of group cognition and shown how research on the processes of alignment involved in these phenomena may be fruitful in uncovering the architecture of group cognitive systems. It would, we think, provide the sort of integration that Rupert thinks is essential for cognitive systems. Finally, we have attempted to dispel some of the skepticism regarding group cognitive systems by responding Rupert's most recent work on this topic. Although, in this paper, we did not advocate for the idea of collective minds, we do suggest that there are a host of resources in cognitive science that can be used to explore the possibility and plausibility of collective cognitive systems.

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