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Synchrony of brains and bodies during implicit interpersonal interaction

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To successfully interact with others, people automatically mimic their actions and feelings. Yet, neurobehavioral studies of interaction are few because of lacking conceptual and experimental frameworks. A recent study introduced an elegantly simple motor task to unravel implicit interpersonal behavioral synchrony and brain function during face-to-face interaction.

Everyday life is full of social interactions – either direct face-to-face encounters or communications mediated via, for example, mobile devices. In these interactions, people try to understand others and to get themselves understood, largely relying on unconsciously formed inferences of the other person's goals and intentions.

Mutual understanding requires a certain level of between-participant similarity in perception and action. For example, comprehension of a verbal message is associated with enhanced synchrony between the brains of the speaker and listener [1]. Along similar lines, brain activity becomes temporally synchronized on time scales of a few seconds in individuals who passively view naturalistic stimuli, such as movies [2], with strengthened synchronization when the viewed events are accompanied by strong emotions [3]. In interaction situations, people often automatically adopt other persons' postures and movement patterns [4], which leads to synchronization of, for instance, walking rhythm, bodily sway, and gesturing. Such unconscious 'mirroring' of other people's actions likely helps to share feelings and goals. Altogether, human brains and minds are not as private as traditionally thought.

Despite the complexity of naturalistic environments, humans are extremely skilful in forming quick impressions of other people and in following their actions. Still, the brain mechanisms underlying inter-subject coordination and cooperation are poorly understood, largely because of the methodological difficulties related to the complex dynamics of interaction situations.

'Two-person neuroscience' (2PN), which records brain activity from two persons at the same time, might provide the necessary methodological and conceptual leaps from the level of individuals to dyads [5,6]. Although reactions to socially relevant stimuli, such as faces, can be easily studied in single-person settings, brain phenomena related to swift social interaction can be captured only when two subjects are studied simultaneously.

Yun and colleagues [7] recently addressed implicit interpersonal interaction by asking two persons to keep their index fingers directed to the finger of the other person in a face-to-face setting. In a training session, one of the subjects served as the leader, moving his/her index finger within a $20 \times 20\text{-cm}^2$ square, and the other person followed the movements. The test-session instruction was to just look at the other person's finger while holding one's own finger stationary. However, the participants tended to unconsciously synchronize the positions of their fingertips, which did not happen after non-social control training with light dots. The authors interpreted the increased synchrony between the finger positions of the two participants to be a 'measurable basis of implicit social interaction'.

These behavioral results are interesting *per se*, as they reveal a tendency for automatic synchronization with others' actions. However, Yun and colleagues went further and also measured scalp EEG simultaneously from the two subjects to identify the brain correlates of the synchronization. Importantly, EEG (as well as MEG) has millisecond time resolution and is a direct measure of neural activity. Yun and collaborators found that intersubject behavioral synchronization (that was increased after the training task) was associated with increased inter-brain, but not intra-brain, phase locking in the theta (4–7.5 Hz) and beta (12–30 Hz) bands.

The simple synchrony task employed by Yun and collaborators is a welcome addition to the limited behavioral repertoire of paradigms to quantify interpersonal synchronization. However, the interpretation of the results raises several questions. Participants engaged in a smooth social interaction may enter co-leadership states, where neither of them is leading or following [8], which results in zero-lag correlations, taken by Yun *et al.* to imply non-intentionality of following. However, intentional entrainment or mutual adaptation during the task can have similar outcomes [9]. It also remains an open question whether the behavioral synchrony in this study increased because of co-operative interaction during the training, as suggested, or whether the training task in fact trained the subjects to ideomotorically follow the other person's finger movements.

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In the EEG analysis, the reported source areas of the phase synchrony included the inferior frontal gyrus, anterior cingulate, parahippocampal gyrus, and postcentral gyrus. However, further confirmation of the exact brain regions would be welcome because all linear source estimates of scalp EEG, including standardized low resolution brain electromagnetic tomography (sLORETA) employed by Yun *et al.*, suffer from significant point spread and cross-talk. Therefore, the distance between the source points cannot be equated with spatial resolution, which, instead, is mainly determined by the distance of the electrodes from the sources and the electromagnetic properties of the head. The high statistical significance of the estimate at certain grid points indicates a significant effect in the measured EEG signals, but it does not imply that these grid points are the true sources of the effect. MEG, either alone or in combination with EEG, could alleviate some of the ambiguity in EEG-only 2PN recordings [10].

The coupling of brain imaging with relevant behavioral measures in this study demonstrates that the 2PN approach can reveal critical aspects of social interaction that cannot be scrutinized in conventional single-subject settings. New analysis techniques still need to be developed for quantifying data from two-person recordings, such as capturing the time-variable properties of the interaction, as well as analyzing properties of the brain network comprising areas from both brains during the interaction.

Behavioral synchrony is critical for group performers, such as contemporary or ballet dancers, players in bands or chamber music ensembles, or soldiers in parade troops. However, synchrony alone is not enough to understand the basis of collaborative joint performance, where actions and interpretations of sensory information have to be shared across the dyad, but the partners have to take different, often counteracting, roles to reach the common goal.

Future research should also address the behavioral and neural basis of multiple hierarchical, simultaneously present time scales of social interaction, such as having a conversation with a friend while walking, with the quick steps synchronized, but the slower turn takings of the conversation anti-synchronized.

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Experimental, cultural, and neural evidence of deliberate prosociality

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A recent *PNAS* paper proposed that prosocial choice might be due to mistakes that disappear with learning. The authors' method for comparing preferences and mistakes might prove useful in other species. However, human evidence from various treatments, cultures, and the brain support the idea that humans are prosocial rather than mistaken.

In a recently published article, Burton-Chellew and West [1] suggest that apparently prosocial actions are just mistakes that humans have to learn to avoid. Their 'mistake hypothesis' (my term) is stated thus: '[. . .] participants enter the game uncertain of what the best decision is to maximize their earnings, and [. . .] they are largely indifferent to the welfare of others and operate with a myopic regard to their own welfare.' ([1], p. 218).

The mistake hypothesis is a possibility that is held dear in economics (where it is called 'confusion'). Respect for the mistake hypothesis in economics is a byproduct of the belief that people are fundamentally selfish, unless genetic kinship, legal or social punishment, or lost future gains from rupturing a repeated-game relationship create calculative

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