**Current Biology 27(9): R346-R348, 2017.**

Cognitive Neuroscience: Synchronizing Brains in the Classroom

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**Traditional cognitive neuroscience is based on studying single individuals in a lab. A paradigm shift is made by a new study that monitors simultaneously the brains of a dozen students in a classroom setting and demonstrates a link between brain-to-brain synchrony and classroom engagement.**

In response to my enthusiastic effort to explain some of the ‘interesting’ cognitive neuroscientific experiments we have been performing in our laboratory, my young son decried: “No Dad, this does not make sense! In real-life situations, we are not waiting to see just a scrambled image on a monitor in a prison-like cell”. My enthusiasm had been short lived: not yet 10 years old, and he had brilliantly spotted (and exposed) the artificiality of the experimental approach routinely adopted by most cognitive neuroscientists. A new study by Dikker *et al*. [1], reported in this issue of *Current Biology*, promises a paradigm shift by demonstrating the feasibility of monitoring the brain activity of a large group of interacting individuals in a naturalistic setting and establishing a clear link between interacting brains and behavior at the group level.

Over the last two decades, we have witnessed an explosion of research aimed at understanding the functioning of the human brain [2]. The brain activities is now recorded in unprecedented detail and analysed with sophisticated data analysis techniques, often borrowed from mathematics and physics [3]. Yet the dominant experimental approach has remained roughly consistent over decades: study a cognitive function in isolation in a sterile laboratory environment. This essentially reductionist practice helps the researcher to come up with a well-controlled experimental design that generates cleaner data and interpretable research findings. Yet it also raises serious doubts, because the tasks studied in the laboratory are not always good representatives of real-life situations, and studying an individual in isolation is almost in complete contradiction to the inherent social fabric of human nature. There is thus a tension between “the generality and tractability of research questions” [4].

Humans are social animals and almost every human behavior needs to be understood in the context of social interactions [5]. In recent years, there has been increasing interest in understanding the neurophysiological basis of social behavior by adopting hyperscanning techniques — simultaneous recording of neural activity from two or more interacting individuals in various interactive paradigms, such as finger tapping, guitar playing, playing in a string quartet, conversational speech, decision making or playing a video game (reviewed in [6]). These studies are slowly breaking the traditional mould of studying one person’s brain in isolation; instead, they emphasize the interactive nature of human cognition [7]. Framed in the dynamical system theory, here brain functions are expressed as a complex and dynamical interplay between brain, behaviour and the environment [8].

Dikker *et al.* [1] took this approach to heart and performed the entire hyperscanning experiment on a group of individuals interacting in a naturalistic setting and over a long period. They used portable electroencephalographic (EEG) units, considerably cheaper than the traditional EEG units in a standard research lab, to simultaneously record brain activities from a class of twelve students in their senior year at a high school in New York City. The students were engaged in various classroom activities while their brain activities were recorded, and the experiment lasted over the entire course of a semester (eleven recording sessions). The study investigated a central question: when students are highly engaged in the classroom (either by classroom material or by interacting with each other), do their brains also show heightened synchrony with one another?

In the classroom, the students in this study were presented with four pre-determined teaching styles: the teacher reading from his lecture notes; the students watching a short instructional video related to the class’ topic; the teacher lecturing to the students; and the students participating in a group discussion. The students rated each activity on how much they enjoyed in each session and also provided an overall rating at the end of the semester; these liking ratings provide an estimate of classroom engagement. Novel data analysis techniques were applied to quantify neural synchrony (coherence between the response in multiple brains) at various levels: the group, that is total synchrony of the whole class; the student-group, how each student’s brain was synchronized with the group; and student–student, how each student’s brain was synchronized with another student’s brain.

The students found watching videos or group discussion more enjoyable than either of the other two teaching styles. Interestingly, a very similar pattern is also revealed by the interbrain synchrony patterns, both at the group level and at the student-group level. In fact, student–group synchrony was robustly and positively correlated with the post-semester enjoyment ratings. Importantly, this enhanced neural synchrony was not merely driven by the common external stimulus [9], but also dependent on student’s focus and their social personality traits such as empathy and group affinity — focused students or students with higher interpersonal traits were associated with higher student-group brain synchrony. Therefore, classroom engagement and neural coherence do go hand in hand.

Dikker *et al.* [1] subsequently investigated the potential link between classroom social dynamics and interbrain synchrony. To elucidate the impact of a teacher, student–group synchrony was compared between two teaching styles differing maximally in terms of teacher’s involvement (videos *versus* lecture). Videos were associated with higher synchrony than lectures, but surprisingly the difference was correlated with students’ liking of the teacher. To investigate the link between classroom configuration and student-student synchrony, the researchers introduced a baseline social condition in which two randomly paired students had face-to-face eye contact for two minutes prior to class. This brief social priming was found to significantly boost interbrain synchrony during subsequent classroom-activities for the pair that had eye contact beforehand. Further, this prior eye contact was catalytic to the interpersonal closeness measures: if two students reported higher social closeness to each other, their brains were more synchronized with each other only if they had face-to-face eye contact just before the class.

This leads to the suggestion that prior eye contact potentially creates a context for joint attention, which subsequently induces higher interbrain synchrony. Joint attention — “two individuals know that they are attending to something in common” [10] — provides a foundation of social cognition and interaction, and is supposed to explain a body of evidence showing higher interbrain synchrony between two interacting individuals coordinating their attention [6]. A recent study [11] has demonstrated that joint attention indeed facilitated higher intra-brain and inter-brain synchrony than did individual attention during a visual search task, and further increases in both synchrony values correlated positively with team efficiency. Interbrain synchrony is also dependent on the nature of attachment between team members. For example, during a co-operation task, dyads involving lovers showed larger prefrontal interbrain synchrony than dyads involving friends and strangers, which was also mirrored by their better task performance [12]. These altogether suggest that interbrain synchrony constitutes an important marker of social interactions, social facilitations and team work [13].

The findings of Dikker *et al.* [1] will, I think, be a source of inspiration to many. The portable inexpensive EEG headsets have been available for a while. Their usage is mainly limited to the gaming and user-interface community, and the cognitive neuroscience community hasn’t warmed up to them yet. The former community is primarily preoccupied with applications on neuro- decoding and feedback, while the latter is perpetually concerned about the lack of laboratory-standard data quality, inconsistent electrode placements, and limited spatial resolution, of these headsets. Admittedly, the current study does not provide much information on the specificity of individual brain regions or neuronal oscillations in the reported enhanced interbrain synchrony in a classroom, so the gain in terms of pure neuroscientific knowledge may not be considered substantial. In this context, the current study should be considered as a proof of concept that it is possible to use these relatively inexpensive headsets and still reliably link brain and behavior in a social and naturalistic (but semi-structured) setting. This could, I hope, pave the way towards bridging these two distant communities, and the outcomes will certainly benefit science, enrich our understanding of the human brain, behavior and society. Time is now ripe to take our neuroimaging kits outside the synthetic laboratory setting. Thanks to Dikker *et al.* [1], now I can show my son a neuroscience article he can relate to.

**References**

1. Dikker, S., Wan, L., Davidesco, I., Oostrik, M., Rowland, J., Michalareas, G., Van Bavel, J.J., Ding, M., and Poeppel, D. (2017). Brain-to-brain synchrony tracks real-world dynamic group interactions in the classroom. Curr. Biol. *27*, 1375-1380.

2. Gazzaniga, M.S. (2004). The Cognitive Neurosciences III, (Boston: MIT press).

3. Bullmore, E., and Sporns, O. (2009). Complex brain networks: graph theoretical analysis of structural and functional systems. Nat. Rev. Neurosci. *10*, 186-198.

4. Hasson, U., and Honey, C.J. (2012). Future trends in Neuroimaging: Neural processes as expressed within real-life contexts. Neuroimage *62*, 1272-1278.

5. Baumeister, R.F. (2005). The Cultural Animal : Human Nature, Meaning, and Social Life, (New York ; Oxford: Oxford University Press).

6. Babiloni, F., and Astolfi, L. (2014). Social neuroscience and hyperscanning techniques: past, present and future. Neurosci. Biobehav. Rev. *44*, 76-93.

7. Varela, F.J., Thompson, E., and Rosch, E. (1991). The Embodied Mind : Cognitive Science and Human Experience, (The MIT Press).

8. Kelso, J.A.S. (1995). Dynamic Patterns : The Self-Organization of Brain and Behavior, (Cambridge, Mass. ; London: MIT Press).

9. Hasson, U., Nir, Y., Levy, I., Fuhrmann, G., and Malach, R. (2004). Intersubject synchronization of cortical activity during natural vision. Science *303*, 1634-1640.

10. Tomasello, M. (1995). Joint attention as social cognition. In Joint Attention: Its Origins and Role in Development, C. Moore and P.J. Dunham, eds. (New York: Psychology Press), pp. 103-130.

11. Szymanski, C., Pesquita, A., Brennan, A.A., Perdikis, D., Enns, J.T., Brick, T.R., Muller, V., and Lindenberger, U. (2017). Teams on the same wavelength perform better: Inter-brain phase synchronization constitutes a neural substrate for social facilitation. Neuroimage *152*, 425-436.

12. Pan, Y., Cheng, X., Zhang, Z., Li, X., and Hu, Y. (2017). Cooperation in lovers: An fNIRS-based hyperscanning study. Hum. Brain Mapp. *38*, 831-841.

13. Toppi, J., Borghini, G., Petti, M., He, E.J., De Giusti, V., He, B., Astolfi, L., and Babiloni, F. (2016). Investigating Cooperative Behavior in Ecological Settings: An EEG Hyperscanning Study. PLoS One *11*, e0154236.

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