Effects of working memory load on tacit coordination and inter-brain synchrony

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Abstract

Theory of mind (ToM) is proposed to allow agents to theorize about others' internal states (e.g., beliefs and intentions). In this way, it facilitates dynamic behavioral adjustment and enables tacit coordination for achieving mutual goals. Working memory (WM) is considered a fundamental part of ToM, as it maintains and actively manipulates social information. However, to what extent WM affects multi-person social coordination on a behavioral, cognitive and neural level is still unknown. To explore this, we employed EEG hyperscanning to simultaneously measure two participants playing a pure coordination game while performing an n-back task. We evaluated differential effects of low and high cognitive load on behavioral coordination and electrophysiologically. We examined WM effects both on single participants by measuring event-related potentials (ERPs) and dyads by estimating a-band interbrain synchronization (IBS), which is said to indicate the formation of shared representations and information transferring between individuals. Linear mixed model analysis revealed that coordinating performance deteriorates under high WM load as compared to low load, an effect that corresponded to significantly less IBS in the right prefrontal and frontal regions. Both regions have been suggested to play a primary role in cognitive control. Additionally, ERP analysis highlighted a P3 component in parietal areas that is often correlated with WM updating. P3 amplitude was significantly decreased under high versus low cognitive load. This result is in line with the idea that WM resources were depleted by the non-social n-back task in the high load condition and thus the effective processing of interpersonal information was impeded. Taken together, our

results demonstrate that WM is crucial for processing social information and can hamper a-band

IBS in the brain areas involved in cognitive control of social processing.

Keywords: tacit coordination, theory of mind, working memory, interbrain synchrony,

hyperscanning, P3 component, social interactions

Effects of working memory load on tacit coordination and inter-brain synchrony

Introduction

"Ὁ ἄνθρωπος φύσει πολιτικὸν ζῷον, καὶ ὁ ἄπολις διὰ φύσιν καὶ οὐ διὰ τύχην ἤτοι φαῦλός ἐστιν, ἢ κρείττων ἢ ἄνθρωπος" [Man is by nature a social animal, and a man that is by nature and not merely by fortune unsocial is either low in the scale of humanity or above it] —

— Aristotle. Politics, Book I, 1253a.1-4.

Human nature has always been recognized as innately social. This sociality is often expressed by individuals preferring more often than not to cooperate (Jagau & van Veelen, 2017; Rand, 2016; Rand & Nowak, 2013; Zaki & Mitchell, 2013) in order to achieve a goal that would otherwise be unattainable (Bruin et al., 2019). Successful cooperative activities, i.e., joint actions, are based on effective social interactions, in which the interacting agents are committed not only to the mutual goal but also to supporting each other and be responsive to each other's behavior (Bratman, 1992). Social interactions are based on the synchronous exchange of information and require consolidation of the available resources to guide the interacting individuals to coordinating their actions (Giraldo & Passino, 2017). In other words, efficient cooperation is achieved by collaborating individuals that dynamically adjust their strategies according to other's intentions and actions.

This is regularly seen in pure coordination games in which players interests perfectly align (Alberti et al., 2011; Colman, 1997; Mehta et al., 1994; Schelling, 1960). In these situations, players usually start with a focal point, i.e., a usually salient feature that leads in the prediction of the coplayer's choice of strategy (Alberti et al., 2011; Colman, 1997; Mehta et al., 1994; Schelling, 1960; Sugden, 1995). These focal points enable the players to follow implied

"coordination rules" (Kwaadsteniet & Dijk, 2012) that over time lead to similar strategy selections and identical actions that ultimately maximize their pay-off (Crawford & Haller, 1990). However, there are many situations in real life where cooperation becomes challenging. People are repeatedly confronted with ambiguous situations in which no salient points can immediately be detected and/or overt communication may be seriously impeded. Under such circumstances, often referred to as "weak" (Van Lange et al., 2007), the game's smooth progression becomes complicated as no obvious cues guide strategy selection (Alberti et al., 2011). Notably, under such circumstances, people manage to tacitly coordinate and succeed in cooperating to accomplish their goals (Kwaadsteniet et al., 2012; Kwaadsteniet & Dijk, 2012; Schelling, 1960; van Dijk et al., 2009). These cases only highlight the fact that there must be a deeper basis on which humans succeed in coordination.

Several studies from the game theory field and socioeconomic sciences have been preoccupied with such questions. In particular, when players are confined to such communication-deprived situations, it is necessary to be able to engage in a learning process through which every gaming act guides and dictates the formulation of the upcoming choice of action (Alberti et al., 2011; Crawford & Haller, 1990). In other words, players solely by observing their partner's previous actions, manage to adjust their own gaming behavior over time to match their partners. This can be achieved by dynamically inferring others' mental states via understanding their perspective and underlying motives (Todd & Galinsky, 2014), adjusting prior beliefs and making predictions on the most probable future actions (Koster-Hale & Saxe, 2013; Premack & Woodruff, 1978). Theorizing about people's internal states is often referred to as mentalizing or Theory of Mind (ToM; Baron-Cohen et al., 1985; Frith, 2012; Wimmer & Perner,

1983). ToM is considered fundamental for successful social interactions (Colman, 1997; Freitas et al., 2019; Galinsky et al., 2005; Kwaadsteniet & Dijk, 2012; van Dijk et al., 2009).

Being able to attribute mental states to oneself and others has been closely related to communication patterns and social efficiency (Resches & Pérez Pereira, 2007; Sidera et al., 2018). For example, people who score higher at ToM tasks, such as false-belief understanding (Wimmer & Perner, 1983), seem to better adapt their behavior to match their partners' communicative system (Resches & Pérez Pereira, 2007). Additionally, ToM is considered crucial for social skills necessary in game play such as creativity (Grant & Berry, 2011), coordination (Galinsky et al., 2005), collaboration and problem solving (Hesse et al., 2015). Even though the importance of such an ability in social contexts is prominent, little attention has been given in its underlying cognitive and neural mechanisms (Bradford et al., 2015; Saxe & Baron-Cohen, 2006), especially not with real-life multi-participant tasks. ToM has often been criticized as a highly complex phenomenon that lacks definition of its explicit constituents, thus making it hard to investigate. Hence, it becomes necessary to delineate and identify the unique contribution of cognitive mechanisms involved in ToM.

ToM has been argued to deploy several subcomponents of Executive Functioning (EF; Austin et al., 2014; Doherty, 2009; Leslie et al., 2004; Miyake et al., 2000; Pellicano, 2007; Perner & Lang, 1999). EF refers to several cognitive processes that are responsible for cognitive control and goal-directed behavior (Diamond, 2013). Even though executive functions are considered essential for the proper functioning of ToM capacities, they are often treated as a unitary variable whose composite study becomes problematic as it fails to account for its multifactorial nature (Aboulafia-Brakha et al., 2011; Gibbons et al., 2007). Without elucidating the specific EF components involved in ToM, it is difficult to clarify how exactly this skill

supports social functioning and how it might be involved in disorders in which people experience social deficits such as autism (Baron-Cohen et al., 1985; Kanner, 1943) and attention-deficit/hyperactivity disorder (ADHD; Fahie & Symons, 2003; Gonzalez-Gadea et al., 2013; Pineda-Alhucema et al., 2018; Tatar & Cansız, 2020). Miyake et al. (2000) attempted to delineate this intricacy by performing a factorial analysis on ToM's underlying cognitive mechanisms. The analysis yielded three main factors that were subsequently confirmed by several studies; *inhibition* of self-perspective representations (Petrashek & Friedman, 2011), *attention shifting* towards another's subjective experience and mental state (Pellicano, 2007) and retention of key information in *working memory* while continuously updating to make appropriate inferences about future events (H. L. Davis & Pratt, 1995; Lecce & Bianco, 2018). Even though there is still a debate on the EF subcomponents' relevance in ToM (Aboulafia-Brakha et al., 2011; Lecce et al., 2017; Lecce & Bianco, 2018; Leslie et al., 2004; Saxe & Baron-Cohen, 2006), one of the most prominent factors influencing ToM skills is Working Memory (WM).

WM has been repeatedly reported to play a pivotal role in perspective-taking contexts (Austin et al., 2014; H. L. Davis & Pratt, 1995; Lecce et al., 2017; Lecce & Bianco, 2018; Mutter et al., 2006; Qureshi & Monk, 2018). This cognitive system is known for retaining and manipulating multiple pieces of task-relevant information simultaneously in order for more complex cognitive tasks to be realized (Baddeley, 2010; Chai et al., 2018; Miyake & Shah, 1999). Accordingly, WM's role is considered to be fundamental for functioning in social environments as it allows an individual to follow the unfolding of a social interaction over time, to track the differences between individuals' perspectives, and finally, to effectively update and adjust one's mental model (Lecce & Bianco, 2018; Meyer & Lieberman, 2012). Another key element of WM is its limited capacity (Baddeley, 1986, 2010; Cowan, 2001; Vergauwe et al.,

2012). WM is a limited pool of cognitive resources which can be easily depleted by preceding or simultaneous tasks (Cowan, 2010; Vergauwe et al., 2012).

Following this line of reasoning, studies report a consistent relation between WM impairments and degraded ToM abilities as well as deficient social interactions. Experiments using concurrent tasks show that cognitive load depletes working memory resources a result that correlates with poor individuals' ability to understand others' mental states, i.e. mentalizing, (Bull et al., 2008; M. H. Davis et al., 1996; Roxβnagel, 2000; Schneider et al., 2012). For example, in a study by (Lin et al., 2010), participants under high WM load, significantly underperformed in a communication task by both taking more time to reach a decision and making more mistakes, i.e. asking for extra clarifications or making more mistakes. The authors suggested that the employment of ToM heavily depends on WM resources. Similarly, (Mills et al., 2015) examined how cognitive load affects multitasking and perspective taking in social interactions with adults and adolescents. The performance of both target groups was significantly affected by WM load. Under high cognitive load, multitasking accuracy declined and participants became slower in social responses when perspective-taking was required implying that exhausting cognitive resources deteriorates the processing of and responding to social cues. These results suggest that considering someone else's perspective is cognitively draining and interferes with other cognitively demanding tasks. In support of these findings, (Qureshi & Monk, 2018) showed that WM is implicated both in the mentalization of another's perspective ("calculation") as well as in the decision of the most suitable mental model that can explain others' behaviour ("selection"). The above findings highlight the primary role of WM in ToM by facilitating interpersonal mentalization.

In this study, we aim to explore how tacit coordination develops over time and how WM affects this ability of dynamically coordinating over time within contexts that require the engagement of ToM. For this reason, we had dyads of participants playing a repeated tacit coordination task. Additionally, to examine the role of working memory, participants had to simultaneously perform a N-back task in which we manipulated cognitive load (Gevins & Cutillo, 1993; Kirchner, 1958a; Owen et al., 2005; Sweet, 2011). In one condition, participants were playing the coordination game under low load, while in the second under high load. We expected that in conditions of high cognitive load as compared to low load, performance in the tacit coordination task would decrease implying impairments in ToM functioning due to WM load interference.

To further investigate what neural mechanisms underlie dynamic tacit coordination and WM in ecologically valid settings, we used inter-brain synchrony (IBS). IBS can be measured in a hyperscanning setup that involves measuring brain activity from two or more interacting individuals by means of a brain imaging technique such as electroencephalography (EEG) and functional magnetic resonance imaging (fMRI; Czeszumski et al., 2020; Montague, 2002). Usually, an estimate of oscillatory phase synchronization is being calculated that represents brain-to-brain coupling. As such, hyperscanning allows for discovering common neural patterns among interacting individuals (Balconi & Vanutelli, 2017) that have been suggested to facilitate the transferring of information and the creation of shared representations (Astolfi et al., 2020; Hasson et al., 2012; Redcay & Schilbach, 2019). Co-representation between partners is said to underly joint actions by enabling the simulation and incorporation of other's actions into one's own action planning that leads in continuous adaptation of one's own behavior to match their partner's (Astolfi et al., 2020; Sebanz et al., 2006). Therefore, investigating interbrain coupling is

a promising method for exploring the mental processes involved in joint actions and capturing the complex dynamics of social interactions as a system (Astolfi et al., 2020; Hasson et al., 2012; Kingsbury & Hong, 2020; Redcay & Schilbach, 2019).

Researchers have shown that inter-brain oscillatory synchronization is correlated with various behaviours that promote or underlie social competence. In particular, IBS has been found to emerge over time in individuals performing coordinated actions (Dumas et al., 2010; Lindenberger et al., 2009; Yun et al., 2012) or in cooperating partners (Lu & Hao, 2019), to increase when individuals decide to cooperate (Astolfi et al., 2011; Fallani et al., 2010; Jahng et al., 2017; Mu et al., 2016; Yun et al., 2012), and even predict group efficiency by means of mutual prosociality (Hu et al., 2017; Reinero et al., 2021). Notably, the reported neural synchronization has been detected in areas suggested to be involved in the mentalising network (Dumas et al., 2010; Fallani et al., 2010; Gallagher & Frith, 2003; Jahng et al., 2017, 2017; Lu & Hao, 2019; Mu et al., 2016; Saxe & Baron-Cohen, 2006). For instance, by EEG hyperscanning and estimating phase-locking values (PLV; i.e. a measure of neural synchrony) it was shown that interacting individuals unconsciously mimicking or imitating each other demonstrate increased synchrony over time in the beta and theta frequency band at the inferior frontal gyrus (IFG) and the ventromedial prefrontal cortex (vmPFC ; Yun et al., 2012) as well as in the alpha band in the right temporoparietal region (RTP; Dumas et al., 2010). Similarly, (Mu et al., 2016) found increased EEG alpha-band IBS synchronization during coordination in central and posterior brain regions that was predictive of coordinating performance. Additionally, in a study by Jahng et al. (2017) participants facing each other while playing a variation of the Prisoner's Dilemma Game exhibited greater IBS in the EEG alpha frequency of the RTP, a result that was predictive of strategy selection (i.e., cooperation or defection). Finally, other studies have shown that

behavioral coordination is associated with synchronized activation in frontal (Hu et al., 2017) and prefrontal regions (Funane et al., 2011; Nozawa et al., 2019; Zhang et al., 2020). Consequently, IBS seems a plausible neuromarker of effective interpersonal coordination and could thus be used to test WM effects on a neuronal level within dynamic social exchanges that require ToM.

Given these points, in the present study, we recorded simultaneously brain activity in two collaborating participants using EEG. The choice of EEG hyperscanning is not arbitrary. On the contrary, EEG is generally praised for its high temporal resolution as opposed to other brain imaging techniques, which can be extremely beneficial in tracking over trials the unfolding of cognitive processes in social interactions (Czeszumski et al., 2020). In addition, since the brain areas of interest are mostly cerebral and not subcortical, EEG measurements are considered adequate to detect localized brain activity (Abreu et al., 2018). Furthermore, EEG allows for more mobility and, thus, contributes to a more naturalistic experimental setting for exploring dynamic social exchanges. Hence, by using EEG hyperscanning, we tested the differential effects WM load has on IBS in the alpha band frequency. Even though, different studies have found supportive evidence of IBS in various frequencies, we focus on alpha oscillations as they seem to be more tightly linked with mental processes such as attention, WM and inhibitory control (Crespo-Garcia et al., 2013; Klimesch, 2012), essential cognitive components underlying the mentalising system (Miyake et al., 2000). Indeed, Guan et al. (2018) using a false belief task to explore the brain oscillations correlated with ToM found increased alpha power in settings requiring understanding another's person perspective. Additionally, alpha band oscillations are more robustly found in brain-to-brain synchronization studies. They have been suggested to constitute a social coordination index (Dumas et al., 2010; Tognoli et al., 2007) by capturing the

neural dynamics of co-learning (Davidesco et al., 2019). Therefore, we hypothesized that under high cognitive load as opposed to low load, IBS in the alpha band frequency will be reduced most prominently in frontoparietal areas associated with WM and ToM, such as the temporoparietal junction, the ventromedial and dorsolateral prefrontal cortex.

Taken together, the aim of the present study is to elucidate on the role of WM as a determinant component of ToM on tacit coordination and identify neurodynamic signatures of naturalistic human interactions. In the tacit coordination task, participants' coordinating performance is expected to overall improve over time. However, high cognitive load as opposed to low load is anticipated to interfere with the typical progression of the game and hamper optimal coordination. Lastly, we presuppose that IBS will correspondingly decline under high cognitive load as compared to low load.

Methods

Ethics Statement

Experiments were approved by the Research Ethical Review Committee (CETO) of the Faculties of Arts, Philosophy, and Theology and Religious Studies of the University of Groningen. Participants gave written consent according to the declaration of Helsinki and were paid for their participation in the study. All data was anonymized.

Participants

Eighty-six healthy young adults (68 females and 18 males) between 18-35 years old (M = 23.14, SD = 4.06) were recruited for this study by advertisement. Only participants of the same sex were paired since previous studies have indicated gender-specific differences in mentalizing capacity (Adenzato et al., 2017) and IBS associated with cooperating performance (Baker et al., 2016; Cheng et al., 2015). Individuals had no prior knowledge of each other. They were all right-

handed, had normal or corrected-to-normal vision and reported having no history of diagnosed psychiatric disorder or neurological injury or illness.

Materials and Apparatus

We used a repeated tacit coordination game to explore coordination over time. As compared to one-shot tacit coordination games, repeated games allow for monitoring the unfolding of ToM (Crawford & Haller, 1990). In essence, starting off with absolutely no knowledge about one's partner's preferences, participants pave the path by trial and error towards a mutual chosen game strategy. In other words, each player chooses an image based on a decision rule that can be updated in each trial according to the choices her partner made in the previous round. In this way, past experiences seem to communicate strategy selection between players and, thus, guide behavioral adaptation that leads to achieving the common goal (Sebanz et al., 2006; Van Huyck et al., 2002).

The stimulus consisted of four abstract randomly-generated images of a chequered pattern of squares with colors or shapes, as shown in Figure 1, adapted by (Alberti et al., 2011). The abstract nature of the images ensured that no cultural bias would influence the selection of one over the others as suggested by (Alberti et al., 2011). Therefore, the selection process was mainly dependent on each participant's subjective aesthetic. The different type of elements (i.e., color and shape) in the images ensured that no carry-over effects would appear between the two cognitive load conditions. This manipulation had an additional goal; to give the chance of a "re-start effect". In other words, in case participants failed to successfully coordinate in a task with the specific type of stimulus, then the usage of a different one could inspire of undertaking a different approach to accomplish the goal, i.e. choosing the same image (Alberti et al., 2011). Each image was an 8x8 array of squares with two fixed elements and one alternating within each

trial. The position of the varying component was randomized across trials. No image was

repeated within the experimental session. Finally, the position of the images appeared in a

different random order between the two participants to prevent the creation of decision rules

based on location, e.g., each time selecting the left-most image.

Figure 1

Sample of experimental stimuli used in the coordination game
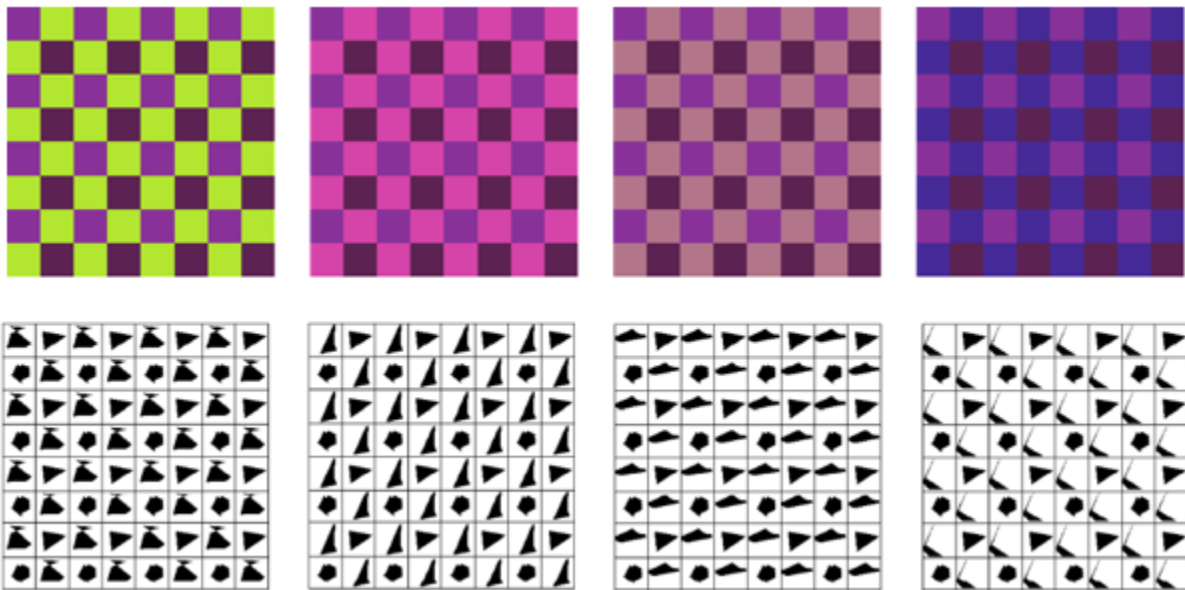
Note. Abstract images adapted from Alberti et al., 2011 among which participants had to choose in the coordination game. Top row displays an example of the color-based stimuli used in the color block, while the lower row shows an example of shape-based stimuli used in the corresponding block.

To test the role of WM in tacit coordination, we employed a classic N-back task

(Kirchner, 1958b). In this task, a series of stimuli, usually numbers, are presented to the

participant and she needs to respond whenever a stimulus from *n* previous trials reoccurs. The

more trials pass before the reoccurrence of the stimulus, the greater the cognitive demands and

thus the harder the task. In the current setting, participants viewed random digits from 1 to 9 at

the middle of the screen between the game trials. There were two levels of difficulty: an easy

condition with low-load (0-back), in which participants had to indicate whether the current digit was an odd or even number, and a difficult condition, with high load (2-back), in which they had to answer whether the present digit was identical to the digit presented two trials before. The experiment followed a 2x2 factorial design (high vs. low load and shape vs. color stimuli). Experimental events were presented on two separate computer monitors at a viewing distance of approximately 75 cm in an experimental room.

Procedure

The participant dyads came to the laboratory, where they were comfortably seated in front of a computer monitor, while having no visual or verbal contact. After receiving a detailed description of the task in written form, they gave written informed consent. Before the start of the experimental phase, the attendees completed three self-report questionnaires assessing personality traits of social anxiety, empathy and autism: Interaction Anxiousness Scale (IAS; (Leary, 1983), Interpersonal Reactivity Index (IRI; M. H. Davis & Davis, 1980), and Autism Spectrum Quotient (ASQ; Baron-Cohen et al., 2001), respectively. IAS assesses subjective affect in social interactions by requiring responders to state how characteristic of themself each statement is, e.g. "I seldom feel anxious in social situations.", on a scale from 1 (not at all characteristic) to 5 (extremely characteristic). IRI is comprised of four main subscales with seven items each answered on 5-Likert scale that account for the multi-dimensional concept of empathy: perspective-taking (PT; e.g. "I try to look at everybody's side of a disagreement before I make a decision"), empathetic concern (EC; e.g. "I am often quite touched by things that I see happen"), fantasy scale (FS; e.g. "I really get involved with the feelings of the characters in a novel"), and personal distress (PD; e.g. "When I see someone get hurt, I tend to remain calm. "). The ASQ includes 50 self-descriptive statements that can be answered on a 4-Likert scale and

assess five dimensions related to the autism spectrum disorder phenotype: social skill, attention switching, attention to detail, communication and imagination. All three questionnaires have been validated as reliable psychometric tools with high internal consistency and retest reliability (Allison et al., 2012; Corte et al., 2007; Hoekstra et al., 2008; Leary & Kowalski, 1993). After the completion of the questionnaires and before continuing to the actual experiment, the EEG set-up was realized. The experimenters remained present throughout the experimental session to ensure that participants followed the instructions and to monitor the proper functioning of the EEG recording.

Dual Behavioral Data Acquisition

The experimental session consisted of one practice phase and two experimental blocks of 90 trials. The tacit coordination's goal was for participants to choose the same image without any communication. The trial, as presented in Figure 2, would start by presenting a set of four abstract images and asking the participant to select one by pressing the corresponding key. After their selection, they would get feedback by seeing the choices of their partner and themselves. The feedback in this way allows the participants to firstly understand their co-player's stimulus preferences and then create certain decision rules, or "emerged conventions" (Alberti et al., 2011) that facilitate achieving their common goal.

In-between the gaming trials, participants would see a number and depending on which block they were on the N-back task, they would have to answer within 3 seconds whether the number was the same as the one presented two trials ago (high load) or if it was an odd or even number (low load). The choice was followed by feedback (correct or wrong). In the high load condition, there was a 33% chance of a 2-back match. Each stimulus was followed by a central fixation cross for a varying duration chosen from the set of numbers from 1000ms to 3000ms in

500ms intervals. Depending on their overall performance, they could get an extra monetary

bonus.

Figure 2

Schematic depiction of experimental procedure
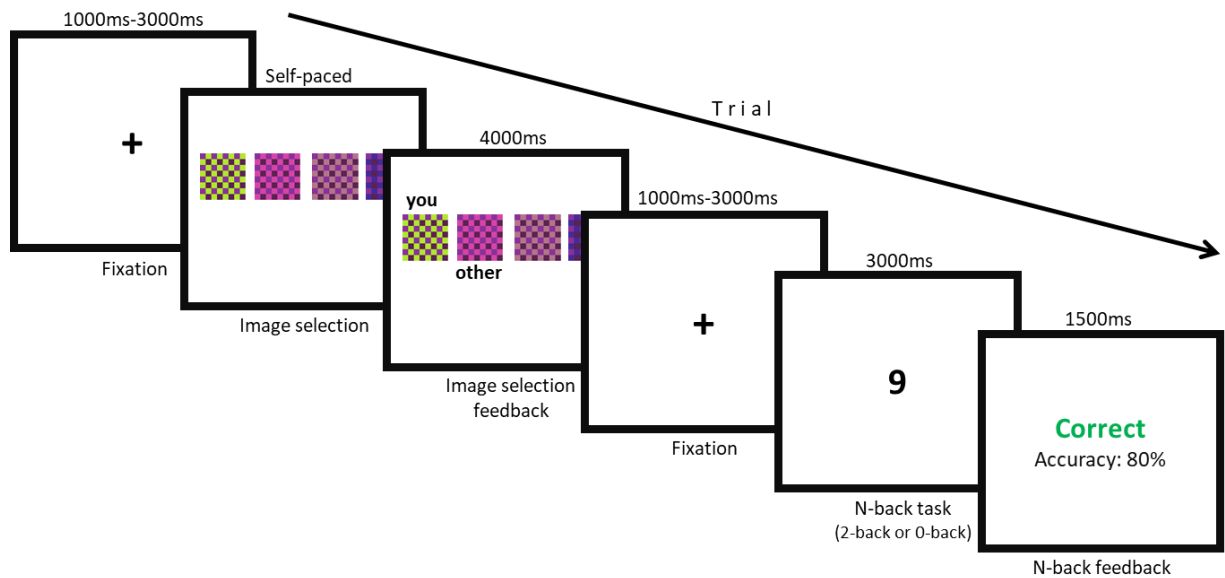
Note. Each trial started with a fixation cross at the middle of the screen for an average of 1.5 seconds. Then, participants would see the images among which they had to guess their partner's choice and choose the same. Once both players had made their choice, feedback would be given showing what they and their partner chose. After 4 seconds, a fixation cross would appear again, and subsequently the number to be judged. If participants where in the high load condition, they had to answer if the number was the same as the one presented two trials ago. Otherwise, they had to indicate if it is an odd or even number. Finally, they would get feedback on their answer and an estimate of overall accuracy.

Dual-EEG Data Acquisition

While the participants were performing the experiment, each brain's electrical activity

was recorded by a 32-channels headcap. Two active electrodes for each pair were used as

reference using a BioSemi ActiveTwo system (BioSemi B.V., Amsterdam, Netherlands) in

Daisy-chain mode, which allowed for simultaneous recording of two individuals. The sampling

rate was set to 512Hz. The electrodes' location followed the international 10–20 system.

Additionally, for EEG reference, 2 external electrodes were placed at the mastoids of each

participant. Another 4 electrodes, 2 at the outer canthi of the eyes and 2 infraorbital and supraorbital to the right eye aligned to the pupil, were used to record horizontal and vertical eye movements electrical activity, i.e., electrooculography (EOG). To reduce motion artifacts, participants were advised to move as little as possible.

Data Analysis

All statistical analysis was performed in R version 4.0.2 (R Core Team, 2020). We used the package lme4 (Bates et al., 2015) for fitting linear mixed models (LMMs) through which we aimed to determine which factors were able to best explain behavioral performance and neural activity. Dyad was introduced as a random-intercept term in each model. In all models, parameters were optimized based on Maximum Likelihood. The usual approach to using LMMs is creating models following an ascending order of complexity and, then, making comparisons between those models. Accordingly, we sequentially added new components to the model and compared it against previous models. We evaluated the models based on the Akaike information criterion (AIC) and likelihood ratio test (LRT) and only kept components that significantly improved model fitness. A model was retained when the associated p-value was lower than .05. Visual inspection of residuals plots did not reveal any obvious deviations from homoscedasticity or normality. Due to time constraints, the questionnaire data was not included in the present analysis.

Behavioral Data

For the behavioral results, a correct response, coded as 1, was considered when the two participants chose the same image. In contrast, incorrect responses consisted of participants having different image choices and were coded as 0. To be able to observe changes of time, we divided each experimental block into 9 trial bins with each bin containing 10 trials and collapsed

blocks according to the experimental condition. We then took the mean of the binary responses for each pair within each bin and calculated a coordination index depicting the proportion of identical choices. This measure of successful coordination was then included as the dependent variable in our models. Bin was entered in the model as a continuous predictor, controlling for the effect of time on coordination behavior. Time was expected to have a systematic positive influence on the coordination, since participants were anticipated to develop shared coordination rules over time. Stimulus type (color *vs* shape) and cognitive load (high *vs* low), were entered in the model as categorical predictors with the latter as the main factor of interest. Finally, upon visual inspection, no influential points were obvious in the data. This was supported by the fact that no coordination indexes were over 3 standard deviations from the overall mean (M = 0.64, SD = 0.11).

Electrophysiological Data

For the pre-processing and the analysis of the EEG signal, we used the Fieldtrip MATLAB-toolbox (Oostenveld et al., 2011). In this way, we obtained the Phase Locking Value for investigating IBS and conducted ERP analysis focusing on the P3 component for examining the effect of working memory. All statistical analysis was performed in R. From the 43 pairs that participated in the experiment, session 1 and 26 failed to successfully record EEG signal due to technical problems. Therefore, they were excluded from the analysis.

Preprocessing

Raw data were re-referenced to the mastoid electrodes. A band-pass filter of 0.1 - 50Hz was applied to padded data for the removal of slow voltage drifts and muscle artifacts. All channels were visually inspected and rejected if noisy or drifting throughout the experiment. After cleaning the data, we segmented it from -1000ms to 1500ms from stimulus onset, i.e., the

period of the images' presentation. All segments were baseline-corrected with reference to the

pre-stimulus interval to remove any arbitrary DC offsets and detrended to clear any linear trends

from the data. Noisy trials were manually rejected after visual inspection. Additionally, single

problematic channels were identified and interpolated. As a last step, Independent Component

Analysis (ICA; (Lisha Sun et al., 2005) was performed to deal with a wide variety of artifacts,

such as eyeblinks and muscle movements. Data from sessions 32 and 43 had too many artifacts

and, thus, was excluded from the analysis.

Interbrain Synchrony Analysis

To evaluate interbrain synchrony, we firstly subjected the artifact-free EEG signal to

time-frequency analysis by means of a convolution operation. A Hanning taper of four cycles per

time window was applied. The Hanning taper is commonly used to EEG signal processing as it

has the best signal-to-noise ratio (SNR; (Hassan & Mahmoud, 2015), it presents adequate

frequency resolution while it preserves amplitude accuracy (Wickramarachi, 2003) and can

handle minor edge artifacts (Cohen, 2014). Frequency of interest was determined as the alpha

band, 9-14Hz (van Vugt et al., 2010, 2012). In this way, we were able to capture the dynamic

phase changes within a trial for both time and frequency domains.

Then, we examined phase synchrony by calculating the Phase Locking Value (PLV;

(Lachaux et al., 1999). PLV is a widely used method to measure brain-to-brain coupling as it has

been found quite robust in depicting the information flow between social interactions (Burgess,

2013). It depicts the consistency of phase difference between two channels at a specific

frequency. The PLV values fall within the range of [0,1], with 0 implying no phase synchrony at

all and 1 perfect phase synchrony between the two signals. To quantify phase synchronization

and obtain the PLVs, we computed the average phase angle for each EEG segment across time

for all paired channels between the two participants on all frequencies within the alpha band. This computation provided 5 different PLVs corresponding to each frequency. To obtain one index value per pair and trial, we averaged them across all frequencies in the alpha band to produce one PLV estimate. Finally, the unique time-averaged PLVs, or PLVs (Burgess, 2013), were matched to their corresponding experimental condition, trial number and behavioral response.

In order to find whether the PLV values are statistically significant, we performed LMMs in R as explained in previous sections. Firstly, we divided the data into the same 9 bins as used for the behavioral analysis and took the average of the PLV value per channel. We additionally matched them to the corresponding behavioral coordination index. Then, separate LMMs were performed for each channel. We started with null models and sequentially moved to more complex models. Bin was again entered as a continuous factor to control for the effect of time, while stimulus type and load condition were included as categorical predictors. All reported areas approximately correspond to the Broadman areas based on the cortical cartography by (Kaiser, 2010). No source localization was realized.

Analysis of event-related potentials (ERPs)

To further assess whether experimental manipulation on working memory load was successful, we ran an ERP analysis. As the P3 component is a relevant EEG component sensitive to working memory load (Luck, 2014; Polich, 2007), we focused on this component. This component has two main subcomponents; P3a peaking at around 200 to 300ms with a frontal maximum that is said to reflect initial evaluation & categorization of the stimulus, and P3b with a parietal maximum peaking at approximately 300 to 500ms post-stimulus suggested to reflect information maintenance and updating in WM (Donchin & Coles, 1988; Hruby & Marsalek,

2003; Luck, 2014; Polich, 2007, 2011). For the purpose of our investigation, we focused on the second component, P3b, which will be for simplicity henceforward referred to as P3. The period selected for this component was between the onset of the images' presentation and prior to the participants' overt expression of decision. During this interval, we expected that subjects were evaluating the outcome of the previous round and making their choice for the next one, while either holding information of the numbers (high load) or not (low load).

From the already pre-processed EEG signal we calculated the average of single-trial EEG epochs to create an ERP waveform per participant per condition. Subsequently, we visually inspected grand-averaged waveforms for the P3 or other potential components. Then, to quantify the P3 amplitude, we averaged the voltage values within a time window of 300ms to 500ms post-stimulus and got a mean amplitude value for each channel. These values were then entered into LMM models as the dependent variable. Stimulus type and load condition were once again entered in the models sequentially as fixed predictors. As opposed to the previous LMMs, instead of entering dyad as a random intercept term, since we had single data points per individual, we used nested models following the nested experimental design. Therefore, subject was entered as a nested-random term. Finally, outlier detection identified one subject's data to be 2 standard deviations away from the mean (M = 2.11, SD = 8.76) and thus this subject was excluded from further analysis.

Results

Behavioral Data

To assess the influence of cognitive load on coordination performance, we started with an intercept-only model. To control for the effect of time during the task on coordination, we added trial bin as a fixed factor. The temporal predictor significantly improved model fitness ($\chi^2(1) =$

151.19, $p < .001$). As displayed in Figure 3, there is a general upward trend showing that

coordination performance increases as a function of time by 0.03 ± 0.002 (*SE*) per bin. This

implies that players manage to better coordinate their image choices over time.

Figure 3

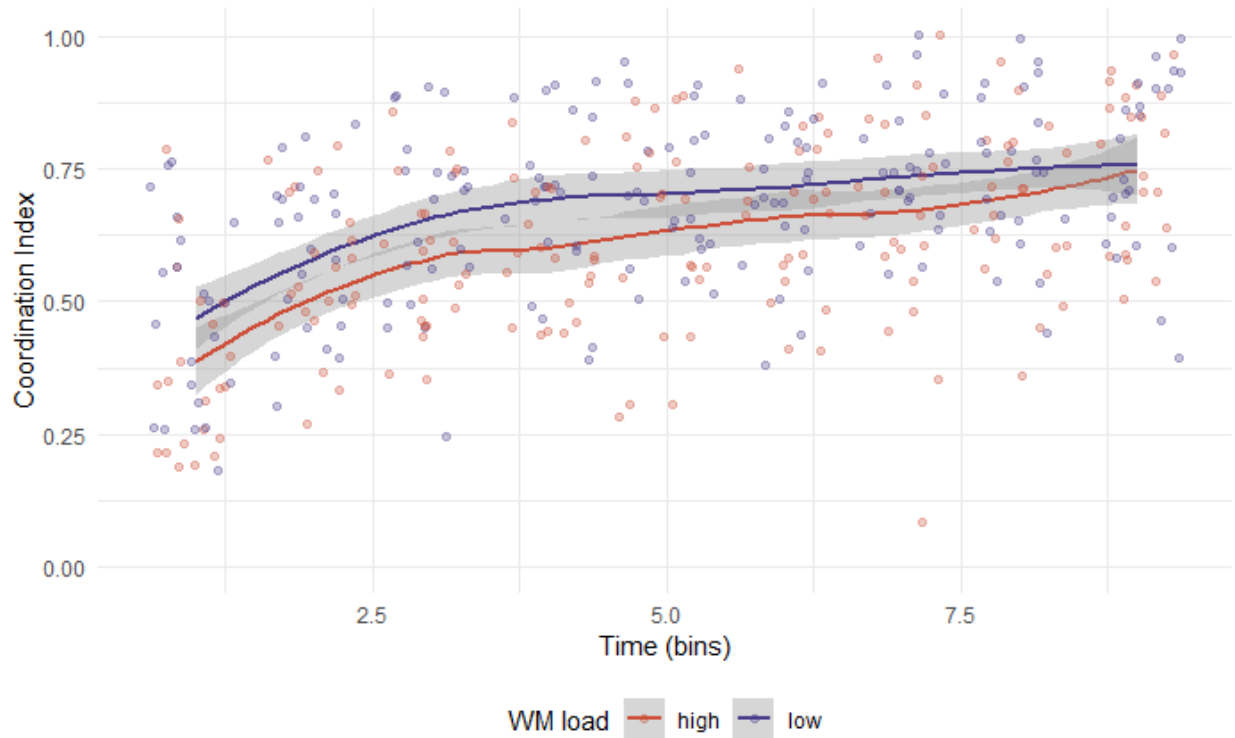*Coordination performance over time*
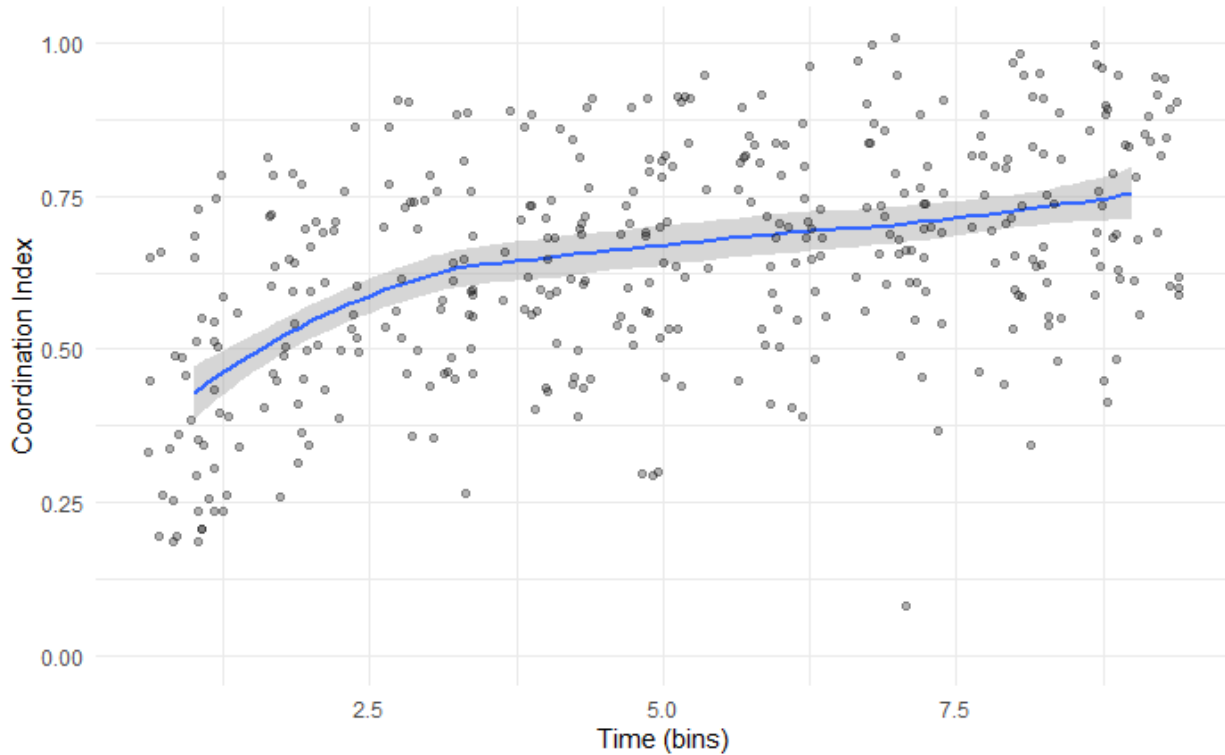
Note. Coordination performance as a function of time with a loess curve and 95% predictive CIs (surrounding grey area). On the x axis, time is represented by the time bins consisting of nine trials each and on the y axis coordination index is capturing mean performance. Each randomly jittered data point represents a pair's mean coordination accuracy per bin.

Based on this model, we then assessed the contribution of additional factors. Firstly, we

evaluated the contribution of stimulus type on coordination performance. The likelihood test

indicated that adding this factor did not improved model fit ($\chi^2(1) = .39$, $p = .53$). Therefore,

stimulus type was excluded from further analysis. Subsequently, we added cognitive load in the

previously supported model. This factor marginally improved our model ($\chi^2(1) = 3.58$, $p = .058$),

with a positive, linear increase in coordination performance in the conditions of low cognitive

load by 0.06 ± 0.03 (SE), as shown in Figure 4.

Figure 4

Coordination performance by cognitive load over time

Note. Coordination performance as a function of cognitive load and time with two fitted loess curves and 95% predictive CIs (surrounding grey areas). On the x axis, time is represented by the same time bins as displayed before and on the y axis coordination index is capturing mean pairs' performance. Randomly jittered data points represent single pairs' means on coordination accuracy per bin for the two different WM load conditions.

Electrophysiological Data

Interbrain Synchrony

To estimate whether there is interbrain synchrony between cooperating individuals, we

began with the intercept only model. To this model we added bin as a fixed predictor to examine

the effect of time. From the separate LMM models and the corresponding likelihood ratio

comparisons, it emerged that for 5 channels model fit improved, as shown in Table 1. It appears

that interbrain synchrony significantly decreases with time spent in the experiment in the left

dorsolateral prefrontal areas, i.e., F3 channel, (b = -.0008, SE = .0004, p = .033) and left pre-

motor cortex (FC1, b = -.0008, SE = .0004, p = .046). On the contrary, IBS seems to significantly

increase in the primary visual cortex (OZ; b = .001, SE = .0004, p = .005), the right anterior

inferior frontal gyrus, i.e., rIFG, (FC6; b = .0008, SE = .0004, p = .045), and in the posterior rIFG

(F8; b = .001, SE = .0004, p = .003).

Table 1

IBS Model Comparisons: Channels showing a significant improvement in model performance by

including an effect of time.

| Channel	$\chi^2(df = 1)$	p-values
F3	4.55	0.033
FC1	3.99	0.046
OZ	7.82	0.005
FC6	4.03	0.045
F8	8.73	0.003

Note. This table demonstrates the results from the model comparison ANOVAs that were conducted between the intercept-only and time models for only the significant channels. Reported here is the channel with the corresponding chi-square (χ^2) value and degrees of freedom (df) as well as p-values of the models' comparisons.

Subsequently, to assess the influence of stimulus type on the data, we increased models'

complexity by adding stimulus type as a fixed effect. Model comparisons were performed

between the previously built models that included the effect of time and the models that included

both time and stimulus type. No model was improved by the stimulus type factor, implying that

stimulus type did not have any statistically significant effect on IBS. Therefore, this predictor

was omitted from further analysis.

Next, working memory load was added to the models. Model fitness improved only for channels F4 ($\chi^2(1) = 5.58$, $p = .018$) and F8 ($\chi^2(1) = 6.25$, $p = .012$). Figure 3 depicts the mean PLV values as a function of time and cognitive load for the above-mentioned channels. In the right pre-supplementary motor area, i.e., pre-SMA, (F4), phase synchrony significantly decreased by - .0004 ± 0.005 (*SE*) when being in the high load condition compared to the low load condition. A similar pattern appeared in the right IFG (F8) in which interbrain synchronization decreased by - .0004 ± 0.005 (*SE*) under high load as opposed to low load.

Figure 5

Mean IBS by cognitive load over time
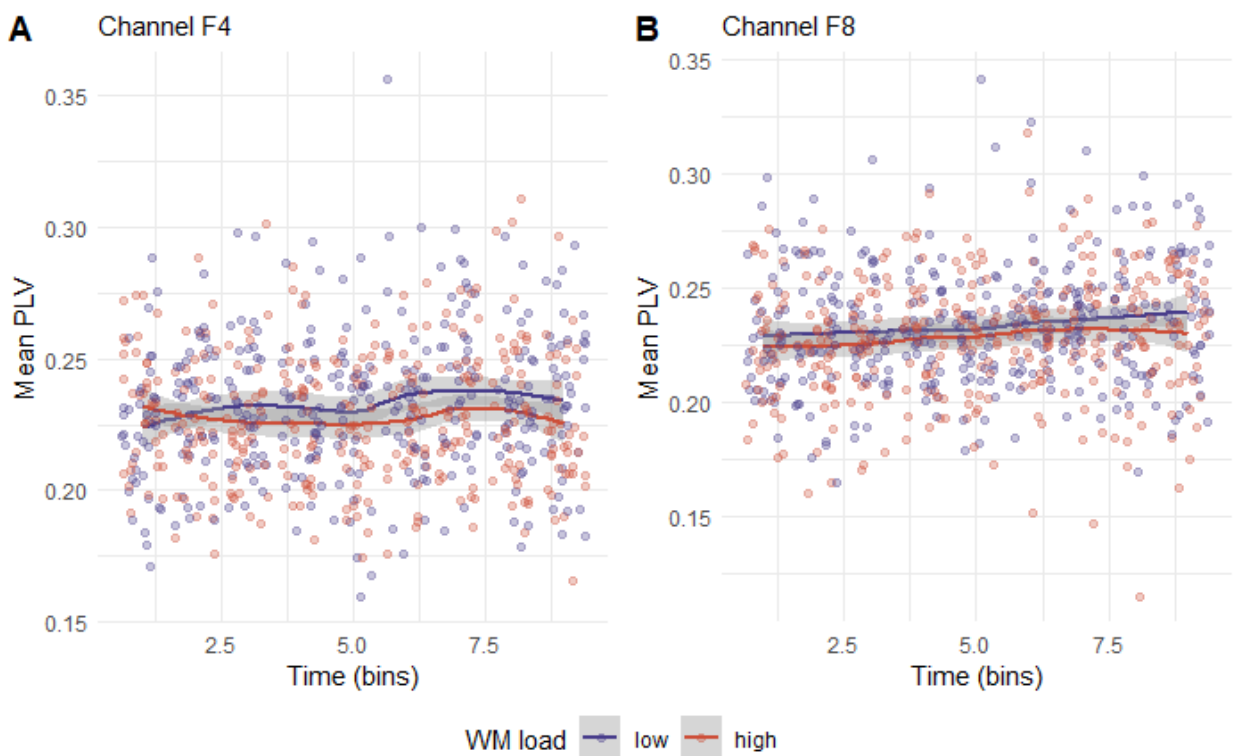
Note. Mean PLV values as a function of time and cognitive load in the two significant channels. Fitted loess curves reflecting the relationship of the different cognitive load conditions and mean PLVs (A) for channel F4 and (B) channel F8. The 95% predictive CIs are depicted by the surrounding grey area. Jittered dots represent the predicted mean PLV-values per session and bin.

Finally, to match the IBS results with the behavioral performance and examine whether brain-coupling is influenced by how well two players can coordinate, we added the coordination

index as a fixed predictor to the previously best models. Model fit improved only for the left

prefrontal cortex (FP1; $\chi^2(1) = 4.05$, $p = .044$), where the more coordinated participants were, the

less IBS they displayed by 0.001 ± 0.005 (*SE*).

ERPs

To test whether the cognitive load had any electrophysiological effect, we investigated

whether a P3 component was significantly different between the two load conditions.

Upon visual inspection via a difference wave topography plot, a maximum mean

amplitude difference emerged between high and low cognitive load at the central parietal area, as

shown in Figure 4B. We then plotted grand average ERP waveforms for the low versus the high

cognitive load condition at the PZ channel, usually reported to have a greater maximum(Hruby

& Marsalek, 2003). As displayed in Figure 4A, mean amplitude within the P3 time window (300-

500ms) is lower for the high load condition (red line) in comparison to the low load (blue line).

Figure 6

ERP Waveforms for low versus high cognitive load and difference topographic plot.
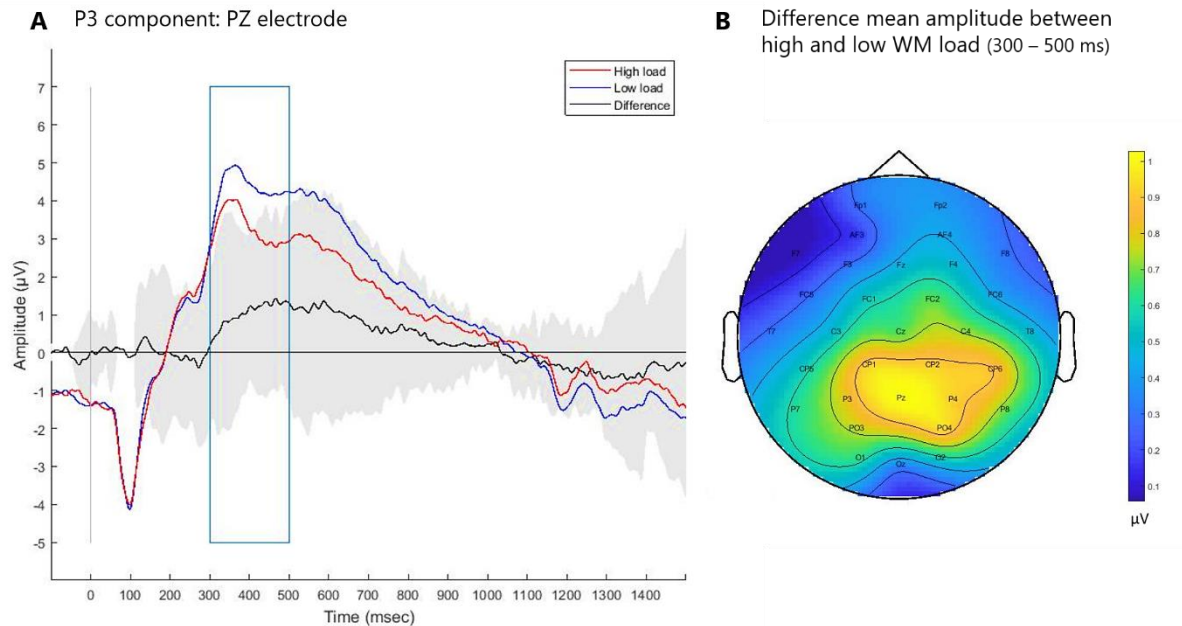
Note. A) Stimulus-locked, grand average ERP waveforms reflecting the P3 components elicited by the high/low WM load conditions and their difference wave at the PZ channel. Shaded area indicates variability around the mean difference wave. Blue rectangle represents the analysis window and time period plotted in the topographic plot. Dotted line at 0 indicates stimulus onset. B) Topographic plot within the P3 window representing the difference in mean amplitude (µV) between high/low WM load.

To statistically test whether the P3 amplitudes are significantly different between the experimental manipulation of cognitive load condition, we conducted LMMs, starting with an intercept-only model. First, stimulus type was added to the models. ANOVA tests revealed that adding this factor improved model fitness for all channels apart from the occipitals, Oz and O2. Specifically, when the stimulus was shape, the mean P3 amplitude decreased at frontal electrodes by on average 1.05 ± 0.24 (SE), at the temporal channels by 0.69 ± 0.25 (SE), at the O1 by 0.77 ± 0.29 (SE) and at the parietal by a mean value of 1.19 ± 0.30 (SE). Since the P3 component depicting memory updating is usually reported in the mid-parietal electrodes, detailed results are reported in Table 2 including model comparisons and beta estimates for each parietal electrode. Then, cognitive load conditions further improved model fitness in some frontal electrodes (AF4,

F4, FC2, FC1, FZ), the central midline (CZ) and in all parietal channels. In detail, when being in

a condition of high WM load, the mean ERP amplitude significantly decreased at the frontal

channels by a value of 0.51 ± 0.22 (SE), at the central midline by 0.65 ± 0.25 (SE) and within the

parietal regions the mean ERP amplitude decreased by a mean value of 0.79 ± 0.29 (SE).

Table 2

ERP Model Comparisons on all parietal channels and beta estimates.

	Models including stimulus type			Models including stimulus type & WM load		
Channel	$\chi^2(df = 1)$	*p*-values	*b* estimate $\pm$ SE	$\chi^2(df = 1)$	*p*-values	*b* estimate $\pm$ SE
CP1	21.49	0.000	- 1.57 $\pm$ 0.31	8.49	0.004	- 0.89 $\pm$ 0.30
CP5	15.39	0.000	- 1.06 $\pm$ 0.26	4.61	0.032	- 0.54 $\pm$ 0.25
P7	8.13	0.004	- 0.79 $\pm$ 0.27	4.86	0.027	- 0.58 $\pm$ 0.26
P3	16.70	0.000	- 1.40 $\pm$ 0.32	5.91	0.015	- 0.77 $\pm$ 0.31
PZ	19.82	0.000	- 1.57 $\pm$ 0.32	9.73	0.002	- 0.99 $\pm$ 0.31
PO3	11.02	0.001	- 1.09 $\pm$ 0.32	5.33	0.021	- 0.72 $\pm$ 0.30
PO4	9.65	0.002	- 1.08 $\pm$ 0.34	7.63	0.006	- 0.91 $\pm$ 0.32
P4	16.63	0.000	- 1.34 $\pm$ 0.31	8.72	0.003	- 0.89 $\pm$ 0.29
P8	4.86	0.027	- 0.70 $\pm$ 0.31	4.88	0.027	- 0.67 $\pm$ 0.30
CP6	11.08	0.001	- 0.96 $\pm$ 0.28	10.26	0.001	- 0.86 $\pm$ 0.26
CP2	24.01	0.000	- 1.55 $\pm$ 0.29	9.68	0.002	-0.88 $\pm$ 0.28

Note. The above table demonstrates the results from the model comparison ANOVAs that were conducted between the intercept-only and stimulus type models as well as the stimulus type models and models including both stimulus type and cognitive load. Only parietal channels are displayed. Reported here is channel with the corresponding chi-square (χ^2) value and degrees of freedom (df), p-values of the models' comparisons and the beta estimates shape in stimulus type and high WM load.

Discussion

The aim of the current study was to investigate the differential effects of WM on tacit

coordination behaviorally and electrophysiologically within dynamic social exchanges. The key

findings of our research demonstrate that even though tacit coordination increases over time, this

learning process can be hampered by WM load. The positive regression weight associated with low cognitive load indicates that pairs can better coordinate their choices when they are not preoccupied with task-irrelevant information.

Additionally, IBS in the alpha band frequency between coordinating subjects decreases in conditions of high WM load within the right pre-SMA and right IFG. This outcome is in line with our hypothesis that neural synchronization, especially in areas involved in cognitive control and perspective taking, would be disrupted by high extraneous working memory demands. Examination of the P3 component corroborated to these findings by revealing a lowered mean amplitude in the high load condition at the interval preceding the overt expression of the subjects' decisions. This outcome is suggestive of subjects' preoccupation with the N-back task to which cognitive resources are being drained by the active maintenance of the arithmetic information. Therefore, there is little availability for creating and manipulating representations capturing partners' perspective.

This study is the first to our knowledge that used a multi-participants design to explore how WM affects tacit coordination behaviorally and neurophysiologically. Firstly, our analysis yielded that pairs of unknown people significantly learn to cooperate over time in an abstract matching game without having any communication. This finding illustrates that people are willing to consider a stranger's perspective possibly by applying ToM skills to reach a convergent strategy that will mutually benefit them. Several studies have demonstrated that efficacy on ToM tasks associates with coordination and communication (Etel & Slaughter, 2019; Ferreira et al., 2021; Imuta et al., 2016). Coordinated action requires players to reason about others preferences, intentions and future actions and progressively update their beliefs to adjust their behavior to their partner's (Crawford & Haller, 1990; de Weerd et al., 2015; Kwaadsteniet

& Dijk, 2012; Van Huyck et al., 2002). ToM seems the most plausible way to optimize individual behavior and facilitate coordination in two-person communication-deprived scenarios. Therefore, the temporal dynamics of collective action studied here reveal that previous choices and outcomes play a crucial role in forming coordinated decisions.

Behavioral coordination improvement over time is additionally supported by the synchronous examination of the two interacting brains. As increased brain-to-brain coupling has been reported under conditions of coordination and cooperation (Dumas et al., 2010; Fallani et al., 2010; Jahng et al., 2017; Lindenberger et al., 2009; Lu & Hao, 2019; Reinero et al., 2021; Toppi et al., 2016; Yun et al., 2012), our results corroborate by showing that IBS in the alpha band in key areas for social functioning is gradually increasing. Specifically, we noted an increase the primary visual cortex and the right IFG. Regarding the IBS increase in the primary visual cortex, a possible explanation could entail that participants over time develop a mechanism that helps them coordinate their actions, often referred to as joint attention (Sebanz et al., 2006). As partners form a decision rule, they tend to search for the stimulus abiding to that rule. For example, if participants implicitly come to converge into selecting the reddest image or the sharpest shape, then it could be possible that they both look for the same stimuli and share the same image processing. Evidence on the function of the primary visual cortex argue that apart from low level image processing (Huff et al., 2021), it can be part of more complex cognitive processes that integrate top-down attentional information (Albers et al., 2013; Kok et al., 2012; Kosslyn et al., 1995; Tong, 2013). In particular, it has been found that the primary visual cortex is significantly influenced by prior expectations that seem to reduce neural activity of bottom-up sensory signals, while acuminate certain visual representations following perceptual adaptation (Kok et al., 2012). Consequently, it seems reasonable to postulate that IBS

increase in this area implies successful integration of previously observed behavior with prior beliefs that lead to a corresponding update of early sensory representations and reflects the formation of shared representations that allows joint attention. In other words, top-down control may facilitate people to gradually attend and/process the same stimuli in a similar manner.

To further support the previous argument, we additionally found that over time along with the improvement in behavioral coordination, IBS in the alpha band also increases in a structure of the ventrolateral prefrontal cortex; the rIFG. The rIFG is a commonly cited area involved in ToM (Carrington & Bailey, 2009; Hartwigsen et al., 2019; Mahy et al., 2014; van der Meer et al., 2011), mostly to provide inhibition of automatic and unsuitable responses (Cieslik et al., 2015; Saxe & Baron-Cohen, 2006). A recent meta-analysis by Hartwigsen et al. (2019) functionally differentiated the region to two subdivisions; the anterior rIFG -corresponding to channel FC6- is involved in more abstract cognitive processes such as mental reasoning, conflict management as well as social and emotional processing, while the more posterior parts - corresponding to channel F8- are responsible for action-related imagery and response inhibition. Therefore, it is no surprise that over time not only do people coordinate better, but also brain activity associated with inhibiting initial egoistic preferences and inferring mental states becomes more synchronous.

Nevertheless, a significant decrease of inter-subject brain activity was noted in the left dorsolateral prefrontal and frontal areas. The noted decrease in IBS might imply a boredom effect that naturally occurs in repetitive tasks (Danckert & Merrifield, 2018; Wagenmakers et al., 2004; Ward, 2002) and results in more off-task thoughts, that are usually self-centered (Turnbull et al., 2019). As Astolfi et al. (2011) reported, more individualistic processes exhibit greater cortical activity in the individual and a corresponding lower neural synchrony between the

partners. Therefore, possible off-task thought could yield out-of-synch signals between the two participants.

With respect to the WM manipulation, significant results emerged both in behavior and in electrophysiology. We found that the high demands of WM load casually led to coordination difficulties, as proven by a general pattern in which high WM load interfered with optimal coordination. This finding could be assumed to reflect a systematic disruption in mentalising about the other's perspective. Although this result is marginally significant, it is still indicative of a general trend according to which for people to accomplish optimal coordination WM resources need to be devoted in the processing of social information (Mills et al., 2015). Various studies argue that mentalizing is an effortful and cognitively demanding process (M. H. Davis et al., 1996; Lin et al., 2010; Spunt & Lieberman, 2013) which can be interrupted by simultaneous irrelevant tasks (Cane et al., 2017; Lin et al., 2010; Mutter et al., 2006; Roxβnagel, 2000; Schneider et al., 2012). Therefore, it is plausible that when the limited WM resources are drawn in another task, the necessary inhibition of automatic self-referential thoughts and the adoption of another's point of view (Bradford et al., 2015; M. H. Davis et al., 1996; Lecce & Bianco, 2018; Lin et al., 2010; Mutter et al., 2006; Roxβnagel, 2000) are impaired. Disrupting the proper functioning of ToM skills, consequently undermines efficient coordination.

In addition, the decreased PLV values under high cognitive load in the alpha band frequencies yield that WM load also affects IBS. Notably, interpersonal synchrony declined in high cognitive load in the right pre-SMA and the posterior part of the rIFG. As increased alpha oscillations have been related to the suppression of task-irrelevant information (Riddle et al., 2020; Sauseng et al., 2009), both observed regions have accordingly been reported to actively

engage in situations requiring high cognitive control (Cieslik et al., 2015; Cole & Schneider, 2007; Hartwigsen et al., 2019).

The right pre-SMA, specifically, seems to be involved in a plethora of functions such as shifting from more automatic responses to more volitional (e.g., Hikosaka & Isoda, 2008), directing actions and conflict resolution (e.g., Usami et al., 2013). Most importantly, though, as reported by (Obeso et al., 2013), this area together with the rIFG specializes in inhibitory control and is strongly associated with WM (Getzmann et al., 2018; L Traverso et al., 2015). In particular, increased activity in the pre-SMA is correlated with response preparation regardless of task characteristics while holding information in WM (Petit et al., 1998; Pollmann & von Cramon, 2000). Moreover, Boucher et al. (2021) provided scientific evidence on how normal inhibitory functioning is negatively affected by high WM demands. Particularly, they found that under high cognitive load, when response inhibition is required, reaction times become prolonged. Other studies also highlight the interdependent role between WM and inhibition. For example, (Kane et al., 2001), by measuring eye movements and saccades, found that individuals with low WM capacity are not only slower in their saccadic responses, but also make more mistakes. In conjunction with the finding of decreased IBS under high load in the rIFG, which as we described earlier is a constituent of the neural basis underlying ToM, it further argues for an interference effect of WM in ToM. Therefore, it seems safe to assume that high WM demands in a non-social task impair efficient suppression of more automatic and "egoistic" representations during dynamic social exchanges and impede successful mentalizing processes. This in turn seems to lead to a decrease in joint actions that are said to base on the ability of forming co-representations (Astolfi et al., 2020; Sebanz et al., 2006).

From the ERP analysis, additional evidence verified the manipulation of cognitive load by an elicited P3 component mostly located in the parietal region. Specifically, we found that mean P3 amplitude in the low load condition was greater as compared to high load just after the onset of the stimulus presentation and before the overt expression of a decision. Since the P3 is often ascribed as a neuromarker for content manipulation in WM (Donchin & Coles, 1988), this finding could imply that participants under low cognitive load are better at dynamically updating their representations to match their partners' beliefs. In a study by (Kourtis et al., 2013), they found P3's amplitude just before joint actions to be enlarged over the mid-parietal electrodes. Their interpretation entailed that greater amplitude reflects adept WM updating for both one's own perspective and their partner's. Moreover, by measuring ERPs on a Go/NoGo task in different social contexts, (Tsai et al., 2006) discovered that the P3 amplitude of the NoGo was greater in the joint action context. They suggested that the NoGo P3 reflects anticipation and greater action monitoring and inhibition when playing with another individual. Following this line of reasoning, we could also presume that when cognitive resources are drawn into an unrelated task, which is evident in a lowered P3 amplitude, WM cannot effectively handle social information. Taken together, it seems that the role of WM is significant in interpersonal exchanges as it mediates efficient inhibitory functioning and allows for adequate processing of social information.

One surprising finding after adding coordination accuracy to the previously best fitted model was the decrease in IBS. Even though coordinating performance was increasing over time and correspondingly IBS, we couldn't establish a relationship between the two variables. Neural synchronization in the left frontopolar cortex (FP1) decreased as a function of coordination accuracy. In other words, the more coordinated the individuals became, the more IBS decreased

in the left foremost part of the prefrontal cortex. This brain area has been found to be involved in explorative as opposed to exploitive behavior (Daw et al., 2006; Mansouri et al., 2017; Raja Beharelle et al., 2015). Exploration is an information seeking mode of behavior for optimizing survival when needs aren't met by the exploitation of the current environmental offers. It requires entertaining and assessing new or alternative options (March, 1991). One explanation, thus, could be that in the current study's tacit coordination task rewards were steadily given by following or exploiting similar decision rules. Therefore, we could postulate that this paradoxical result of decreased inter-subject brain activity might actually reflect a decreased need for exploring the environment for drastically new information to update decision rules. However, this interpretation remains highly susceptible and would require further investigation.

Limitations and future advancements

A limitation of this study stems from the hyperscanning method used. Measuring simultaneous neural activity from two or more individuals is a relatively new approach and with this a lot of uncertainty over its validity follows (Nam et al., 2020). In particular, Burgess (2013) analyzed different methods for evaluating IBS measurements among which was PLV values we have used in this study. What they noted was that even though this method is widely used as an index for brain-to-brain coupling, caution should be taken as it may frequently reveal spurious hyper-connections. PLV values by depicting the degree of consistency in phase-difference do not control for the nature of the noted phase difference, i.e., coincidental or related to actual information exchange. Hence, it is advisable the reader to take this into consideration. Future research could potentially use multiple hyperscanning analyses such as the circular correlation co-efficient (CCorr) or mutual information via Kraskov's Mutual Information estimator (KMI) that have been proposed to be less biased (Burgess, 2013).

Another issue to consider concerns the statistical analysis of both the behavioral and IBS data. As described in the Data Analysis section, in order to understand the temporal dynamics of behavioral and cognitive processes, we split the data into manually decided bins of trials and calculated their mean. However, this practice is not optimal as the definition of bin boundaries is arbitrary and different bin sizes might yield different results (Wainer et al., 2006). In other words, larger bins are smoother and lose detailed information about small fluctuations in the data, whereas smaller bins might be too sensitive in these variations and thus hard to handle and interpret. Additionally, this could potentially lead to misleading outcomes or important loss of information (van Leeuwen et al., 2019; Wainer et al., 2006). For instance, some bins, especially in the IBS, were missing data due to the EEG pre-processing. Therefore, not all bins contained the same amount of signal input and as such distortions might have been introduced (van Leeuwen et al., 2019). Taking this into account, future research could use better alternatives to examine the temporal dynamics of interpersonal cognitive process such as polynomial models or splines, e.g., generalized additive models (Flom, 2018).

Additionally, in this study we only focused on the alpha band frequency since it the one mostly associated with cognitive processes (Crespo-Garcia et al., 2013; Klimesch, 2012; Riddle et al., 2020; Ward, 2003) and has been said to support false belief processing (Guan et al., 2018). Notwithstanding, evidence also indicate that other frequencies could be involved and therefore would worth to be explored. For example, gamma frequencies are suggested to reflect attentional and memory processes (Başar, 2013; Ward, 2003) or theta oscillations that have been supported to play a role in manipulating content in WM (Herweg et al., 2020; Riddle et al., 2020). Another interesting suggestion for future studies could also be the examination ERP latencies. Especially, given our results, it would be interesting to inspect if there is a significant differentiation between

the cognitive load conditions in the onset latency of the P3. P3 onset latency has been reported to reflect inhibitory control (Wessel & Aron, 2015). Accordingly, studying P3 onset latency could be considered as a neurophysiological proxy of response inhibition. In this way, since our IBS results under high WM load indicated significant decrease in brain areas involved in inhibitory control, P3 latency could help establish a putative mediating role of WM between efficient inhibition and successful interpersonal exchanges.

Finally, our results are of great significance since they show that WM is an essential cognitive process for social interactions. Follow-up studies could extend these results and investigate what is the role of WM in social exchanges in people suffering from various disorders such social anxiety and schizophrenia. In particular, anxiety consists of an interesting phenomenon as, on the one hand, it seems to improve accuracy in perspective-taking mentalization (Knight et al., 2019; Zainal & Newman, 2018), while, on the other hand, it impedes working memory performance (Darke, 1988; Moran, 2016; Oei et al., 2006; but also see, Lukasik et al., 2019). Therefore, this experimental paradigm could be useful in delineating the underlying cognitive and neural components that sustain certain disorders and help create effective applications that apart from the individual recognize the dynamic social context in which she lives.

Conclusion

Taken together, this study provided evidence supporting the idea that different individuals can over time learn to cooperate without having direct communication by coordinating their behaviors to achieve a mutual goal. This outcome was also reflected in emerging interbrain synchrony in mentalizing areas between the interacting individuals, a result that argues in favor of the creation of shared representations for the accomplishment of mutual benefit. Importantly,

cognitive control processes play a pivotal role in the successful completion of such tasks. As working memory demands increase, verified by a decreased P3 amplitude component, coordination deteriorates and the neural activity between the pair members falls out of synch in areas crucial for inhibitory control. To the best of our knowledge, this is the first study that investigated the role of WM in dynamic, real-time dyadic interactions

References

Aboulafia-Brakha, T., Christe, B., Martory, M.-D., & Annoni, J.-M. (2011). Theory of mind tasks and executive functions: A systematic review of group studies in neurology. *Journal of Neuropsychology*, *5*(Pt 1), 39–55. https://doi.org/10.1348/174866410X533660

Abreu, R., Leal, A., & Figueiredo, P. (2018). EEG-Informed fMRI: A Review of Data Analysis Methods. *Frontiers in Human Neuroscience*, *12*. https://doi.org/10.3389/fnhum.2018.00029

Adenzato, M., Brambilla, M., Manenti, R., De Lucia, L., Trojano, L., Garofalo, S., Enrici, I., & Cotelli, M. (2017). Gender differences in cognitive Theory of Mind revealed by transcranial direct current stimulation on medial prefrontal cortex. *Scientific Reports*, *7*(1), 41219. https://doi.org/10.1038/srep41219

Albers, A. M., Kok, P., Toni, I., Dijkerman, H. C., & de Lange, F. P. (2013). Shared Representations for Working Memory and Mental Imagery in Early Visual Cortex. *Current Biology*, *23*(15), 1427–1431. https://doi.org/10.1016/j.cub.2013.05.065

Alberti, F., Heap, S. H., & Sugden, R. (2011). The emergence of salience: An experimental investigation. In *Working Paper series, University of East Anglia, Centre for Behavioural and Experimental Social Science (CBESS)* (No. 11–01; Working Paper Series, University of East Anglia, Centre for Behavioural and Experimental Social Science (CBESS)).

School of Economics, University of East Anglia, Norwich, UK.

https://ideas.repec.org/p/uea/wcbess/11-01.html

Allison, C., Auyeung, B., & Baron-Cohen, S. (2012). Toward Brief "Red Flags" for Autism

Screening: The Short Autism Spectrum Quotient and the Short Quantitative Checklist in

1,000 Cases and 3,000 Controls. *Journal of the American Academy of Child & Adolescent

Psychiatry*, *51*(2), 202-212.e7. https://doi.org/10.1016/j.jaac.2011.11.003

Astolfi, L., Toppi, J., Ciaramidaro, A., Vogel, P., Freitag, C. M., & Siniatchkin, M. (2020).

Raising the bar: Can dual scanning improve our understanding of joint action?

NeuroImage, *216*, 116813. https://doi.org/10.1016/j.neuroimage.2020.116813

Astolfi, L., Toppi, J., De Vico Fallani, F., Vecchiato, G., Cincotti, F., Wilke, C., Yuan, H., Mattia,

D., Salinari, S., He, B., & Babiloni, F. (2011). Imaging the Social Brain by Simultaneous

Hyperscanning during Subject Interaction. *IEEE Intelligent Systems*, *26*(5), 38–45.

https://doi.org/10.1109/MIS.2011.61

Austin, G., Groppe, K., & Elsner, B. (2014). The reciprocal relationship between executive

function and theory of mind in middle childhood: A 1-year longitudinal perspective.

Frontiers in Psychology, *5*. https://doi.org/10.3389/fpsyg.2014.00655

Baddeley, A. (1986). *Working memory* (pp. xi, 289). Clarendon Press/Oxford University Press.

Baddeley, A. (2010). Working memory. *Current Biology*, *20*(4), R136–R140.

https://doi.org/10.1016/j.cub.2009.12.014

Baker, J. M., Liu, N., Cui, X., Vrticka, P., Saggar, M., Hosseini, S. M. H., & Reiss, A. L. (2016).

Sex differences in neural and behavioral signatures of cooperation revealed by fNIRS

hyperscanning. *Scientific Reports*, *6*, 26492. https://doi.org/10.1038/srep26492

Balconi, M., & Vanutelli, M. E. (2017). Cooperation and Competition with Hyperscanning Methods: Review and Future Application to Emotion Domain. *Frontiers in Computational Neuroscience*, *11*, 86. https://doi.org/10.3389/fncom.2017.00086

Baron-Cohen, S., Leslie, A. M., & Frith, U. (1985). Does the autistic child have a "theory of mind"? *Cognition*, *21*(1), 37–46. https://doi.org/10.1016/0010-0277(85)90022-8

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The autism-spectrum quotient (AQ): Evidence from Asperger syndrome/high-functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders*, *31*(1), 5–17. https://doi.org/10.1023/a:1005653411471

Başar, E. (2013). A review of gamma oscillations in healthy subjects and in cognitive impairment. *International Journal of Psychophysiology*, *90*(2), 99–117. https://doi.org/10.1016/j.ijpsycho.2013.07.005

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software*, *67*(1), 1–48. https://doi.org/10.18637/jss.v067.i01

Boucher, L., Viparina, B., & Collins, W. M. (2021). Working Memory Load Selectively Influences Response Inhibition in a Stop Signal Task. *Psychological Reports*, *124*(3), 1268–1281. https://doi.org/10.1177/0033294120928271

Bradford, E. E. F., Jentzsch, I., & Gomez, J.-C. (2015). From self to social cognition: Theory of Mind mechanisms and their relation to Executive Functioning. *Cognition*, *138*, 21–34. https://doi.org/10.1016/j.cognition.2015.02.001

Bratman, M. E. (1992). Shared Cooperative Activity. *The Philosophical Review*, *101*(2), 327–341. https://doi.org/10.2307/2185537

Bruin, B. J., Dekker, H. C., & Groot, T. L. C. M. (2019). Dynamic influences on cooperation in a

    social dilemma: How type of experience and communication affect behavioral spillovers.

    PLOS ONE, *14*(3), e0213038. https://doi.org/10.1371/journal.pone.0213038

Bull, R., Phillips, L. H., & Conway, C. A. (2008). The role of control functions in mentalizing:

    Dual-task studies of theory of mind and executive function. *Cognition*, *107*(2), 663–672.

    https://doi.org/10.1016/j.cognition.2007.07.015

Burgess, A. P. (2013). On the interpretation of synchronization in EEG hyperscanning studies: A

    cautionary note. *Frontiers in Human Neuroscience*, *7*.

    https://doi.org/10.3389/fnhum.2013.00881

Carrington, S. J., & Bailey, A. J. (2009). Are there theory of mind regions in the brain? A review

    of the neuroimaging literature. *Human Brain Mapping*, *30*(8), 2313–2335.

    https://doi.org/10.1002/hbm.20671

Chai, W. J., Abd Hamid, A. I., & Abdullah, J. M. (2018). Working Memory From the

    Psychological and Neurosciences Perspectives: A Review. *Frontiers in Psychology*, *9*,

    401. https://doi.org/10.3389/fpsyg.2018.00401

Cheng, X., Li, X., & Hu, Y. (2015). Synchronous brain activity during cooperative exchange

    depends on gender of partner: A fNIRS-based hyperscanning study. *Human Brain

    Mapping*, *36*(6), 2039–2048. https://doi.org/10.1002/hbm.22754

Cieslik, E. C., Mueller, V. I., Eickhoff, C. R., Langner, R., & Eickhoff, S. B. (2015). Three key

    regions for supervisory attentional control: Evidence from neuroimaging meta-analyses.

    Neuroscience and Biobehavioral Reviews, *0*, 22–34.

    https://doi.org/10.1016/j.neubiorev.2014.11.003

Cohen, M. X. (2014). *Analyzing neural time series data: Theory and practice*. The MIT Press.

Cole, M. W., & Schneider, W. (2007). The cognitive control network: Integrated cortical regions with dissociable functions. *NeuroImage*, *37*(1), 343–360. https://doi.org/10.1016/j.neuroimage.2007.03.071

Colman, A. M. (1997). Salience and focusing in pure coordination games. *Journal of Economic Methodology*, *4*(1), 61–81. https://doi.org/10.1080/13501789700000004

Corte, K. D., Buysse, A., Verhofstadt, L., Roeyers, H., Ponnet, K., & Davis, M. (2007). Measuring Empathic Tendencies: Reliability And Validity of the Dutch Version of the Interpersonal Reactivity Index. *Psychologica Belgica*, *47*(4), 235–260. https://doi.org/10.5334/pb-47-4-235

Cowan, N. (2001). The magical number 4 in short-term memory: A reconsideration of mental storage capacity. *Behavioral and Brain Sciences*, *24*(1), 87–114. https://doi.org/10.1017/S0140525X01003922

Cowan, N. (2010). The Magical Mystery Four: How Is Working Memory Capacity Limited, and Why? *Current Directions in Psychological Science*, *19*(1), 51–57. https://doi.org/10.1177/0963721409359277

Crawford, V. P., & Haller, H. (1990). Learning How to Cooperate: Optimal Play in Repeated Coordination Games. *Econometrica*, *58*(3), 571–595. https://doi.org/10.2307/2938191

Crespo-Garcia, M., Pinal, D., Cantero, J. L., Díaz, F., Zurrón, M., & Atienza, M. (2013). Working Memory Processes Are Mediated by Local and Long-range Synchronization of Alpha Oscillations. *Journal of Cognitive Neuroscience*, *25*(8), 1343–1357. https://doi.org/10.1162/jocn_a_00379

Czeszumski, A., Eustergerling, S., Lang, A., Menrath, D., Gerstenberger, M., Schuberth, S., Schreiber, F., Rendon, Z. Z., & König, P. (2020). Hyperscanning: A Valid Method to

Study Neural Inter-brain Underpinnings of Social Interaction. *Frontiers in Human Neuroscience*, *14*. https://doi.org/10.3389/fnhum.2020.00039

Darke, S. (1988). Anxiety and working memory capacity. *Cognition & Emotion*, *2*(2), 145–154. https://doi.org/10.1080/02699938808408071

Davidesco, I., Laurent, E., Valk, H., West, T., Dikker, S., Milne, C., & Poeppel, D. (2019). Brain-to-brain synchrony predicts long-term memory retention more accurately than individual brain measures. *BioRxiv*, 644047. https://doi.org/10.1101/644047

Davis, H. L., & Pratt, C. (1995). The development of children's theory of mind: The working memory explanation. *Australian Journal of Psychology*, *47*(1), 25–31. https://doi.org/10.1080/00049539508258765

Davis, M. H., Conklin, L., Smith, A., & Luce, C. (1996). Effect of perspective taking on the cognitive representation of persons: A merging of self and other. *Journal of Personality and Social Psychology*, *70*(4), 713–726. https://doi.org/10.1037/0022-3514.70.4.713

Davis, M. H., & Davis, M. H. (1980). A multidimensional approach to individual difference in empathy. *JSAS Catalog of Selected Documents in Psychology*, 85.

Daw, N. D., O'Doherty, J. P., Dayan, P., Seymour, B., & Dolan, R. J. (2006). Cortical substrates for exploratory decisions in humans. *Nature*, *441*(7095), 876–879. https://doi.org/10.1038/nature04766

de Weerd, H., Verbrugge, R., & Verheij, B. (2015). Higher-order theory of mind in the Tacit Communication Game. *Biologically Inspired Cognitive Architectures*, *11*, 10–21. https://doi.org/10.1016/j.bica.2014.11.010

Diamond, A. (2013). Executive Functions. *Annual Review of Psychology*, *64*, 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Doherty, M. J. (2009). *Theory of mind: How children understand others' thoughts and feelings*.

Psychology Press.

Donchin, E., & Coles, M. G. (1988). Is the P300 component a manifestation of context updating?

Behavioral and Brain Sciences, *11*(3), 357–427.

https://doi.org/10.1017/S0140525X00058027

Dumas, G., Nadel, J., Soussignan, R., Martinerie, J., & Garnero, L. (2010). Inter-Brain

Synchronization during Social Interaction. *PLOS ONE*, *5*(8), e12166.

https://doi.org/10.1371/journal.pone.0012166

Etel, E., & Slaughter, V. (2019). Theory of mind and peer cooperation in two play contexts.

Journal of Applied Developmental Psychology, *60*, 87–95.

https://doi.org/10.1016/j.appdev.2018.11.004

Fahie, C. M., & Symons, D. K. (2003). Executive functioning and theory of mind in children

clinically referred for attention and behavior problems. *Journal of Applied Developmental

Psychology*, *24*(1), 51–73. https://doi.org/10.1016/S0193-3973(03)00024-8

Fallani, F. D. V., Nicosia, V., Sinatra, R., Astolfi, L., Cincotti, F., Mattia, D., Wilke, C., Doud, A.,

Latora, V., He, B., & Babiloni, F. (2010). Defecting or Not Defecting: How to "Read"

Human Behavior during Cooperative Games by EEG Measurements. *PLOS ONE*, *5*(12),

e14187. https://doi.org/10.1371/journal.pone.0014187

Ferreira, P. L., Santos, F. C., & Pequito, S. (2021). Risk sensitivity and theory of mind in human

coordination. *PLOS Computational Biology*, *17*(7), e1009167.

https://doi.org/10.1371/journal.pcbi.1009167

Flom, P. (2018, September 8). *Why binning continuous data is almost always a mistake*. Medium. https://medium.com/@peterflom/why-binning-continuous-data-is-almost-always-a-mistake-ad0b3a1d141f

Freitas, J. D., Thomas, K., DeScioli, P., & Pinker, S. (2019). Common knowledge, coordination, and strategic mentalizing in human social life. *Proceedings of the National Academy of Sciences*, *116*(28), 13751–13758. https://doi.org/10.1073/pnas.1905518116

Frith, C. D. (2012). The role of metacognition in human social interactions. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *367*(1599), 2213–2223. https://doi.org/10.1098/rstb.2012.0123

Funane, T., Kiguchi, M., Atsumori, H., Sato, H., Kubota, K., & Koizumi, H. (2011). Synchronous activity of two people's prefrontal cortices during a cooperative task measured by simultaneous near-infrared spectroscopy. *Journal of Biomedical Optics*, *16*(7), 077011. https://doi.org/10.1117/1.3602853

Galinsky, A. D., Ku, G., & Wang, C. S. (2005). Perspective-Taking and Self-Other Overlap: Fostering Social Bonds and Facilitating Social Coordination. *Group Processes & Intergroup Relations*, *8*(2), 109–124. https://doi.org/10.1177/1368430205051060

Gallagher, H. L., & Frith, C. D. (2003). Functional imaging of "theory of mind." *Trends in Cognitive Sciences*, *7*(2), 77–83. https://doi.org/10.1016/s1364-6613(02)00025-6

Getzmann, S., Wascher, E., & Schneider, D. (2018). The role of inhibition for working memory processes: ERP evidence from a short-term storage task. *Psychophysiology*, *55*(5), e13026. https://doi.org/10.1111/psyp.13026

Gevins, A., & Cutillo, B. (1993). Spatiotemporal dynamics of component processes in human

  working memory. *Electroencephalography and Clinical Neurophysiology*, *87*(3), 128–

  143. https://doi.org/10.1016/0013-4694(93)90119-g

Gibbons, Z. C., Snowden, J. S., Thompson, J. C., Happé, F., Richardson, A., & Neary, D. (2007).

  Inferring thought and action in motor neurone disease. *Neuropsychologia*, *45*(6), 1196–

  1207. https://doi.org/10.1016/j.neuropsychologia.2006.10.008

Giraldo, L. F., & Passino, K. M. (2017). Dynamics of Cooperation in a Task Completion Social

  Dilemma. *PLOS ONE*, *12*(1), e0170604. https://doi.org/10.1371/journal.pone.0170604

Gonzalez-Gadea, M. L., Baez, S., Torralva, T., Castellanos, F. X., Rattazzi, A., Bein, V., Rogg,

  K., Manes, F., & Ibanez, A. (2013). Cognitive variability in adults with ADHD and AS:

  Disentangling the roles of executive functions and social cognition. *Research in*

  Developmental Disabilities, *34*(2), 817–830. https://doi.org/10.1016/j.ridd.2012.11.009

Grant, A. M., & Berry, J. W. (2011). The Necessity of Others is The Mother of Invention:

  Intrinsic and Prosocial Motivations, Perspective Taking, and Creativity. *Academy of*

  Management Journal, *54*(1), 73–96. https://doi.org/10.5465/amj.2011.59215085

Guan, Y., Farrar, M. J., & Keil, A. (2018). Oscillatory Brain Activity Differentially Reflects False

  Belief Understanding and Complementation Syntax Processing. *Cognitive, Affective &*

  Behavioral Neuroscience, *18*(1), 189–201. https://doi.org/10.3758/s13415-018-0565-9

Hartwigsen, G., Neef, N. E., Camilleri, J. A., Margulies, D. S., & Eickhoff, S. B. (2019).

  Functional Segregation of the Right Inferior Frontal Gyrus: Evidence From Coactivation-

  Based Parcellation. *Cerebral Cortex*, *29*(4), 1532–1546.

  https://doi.org/10.1093/cercor/bhy049

Hassan, M. A., & Mahmoud, E. A. (2015). A Comparison between Windowing FIR Filters for Extracting the EEG Components. *Journal of Biosensors & Bioelectronics*, *06*(04). https://doi.org/10.4172/2155-6210.1000191

Hasson, U., Ghazanfar, A. A., Galantucci, B., Garrod, S., & Keysers, C. (2012). Brain-to-Brain coupling: A mechanism for creating and sharing a social world. *Trends in Cognitive Sciences*, *16*(2), 114–121. https://doi.org/10.1016/j.tics.2011.12.007

Herweg, N. A., Solomon, E. A., & Kahana, M. J. (2020). Theta Oscillations in Human Memory. *Trends in Cognitive Sciences*, *24*(3), 208–227. https://doi.org/10.1016/j.tics.2019.12.006

Hesse, F., Care, E., Buder, J., Sassenberg, K., & Griffin, P. (2015). A Framework for Teachable Collaborative Problem Solving Skills. In P. Griffin & E. Care (Eds.), *Assessment and Teaching of 21st Century Skills* (pp. 37–56). Springer Netherlands. https://doi.org/10.1007/978-94-017-9395-7_2

Hikosaka, O., & Isoda, M. (2008). Brain mechanisms for switching from automatic to controlled eye movements. *Progress in Brain Research*, *171*, 375–382. https://doi.org/10.1016/S0079-6123(08)00655-9

Hoekstra, R. A., Bartels, M., Cath, D. C., & Boomsma, D. I. (2008). Factor Structure, Reliability and Criterion Validity of the Autism-Spectrum Quotient (AQ): A Study in Dutch Population and Patient Groups. *Journal of Autism and Developmental Disorders*, *38*(8), 1555–1566. https://doi.org/10.1007/s10803-008-0538-x

Hruby, T., & Marsalek, P. (2003). Event-related potentials—The P3 wave. *Acta Neurobiologiae Experimentalis*, *63*(1), 55–63.

Hu, Y., Hu, Y., Li, X., Pan, Y., & Cheng, X. (2017). Brain-to-brain synchronization across two persons predicts mutual prosociality. *Social Cognitive and Affective Neuroscience*, *12*(12), 1835–1844. https://doi.org/10.1093/scan/nsx118

Huff, T., Mahabadi, N., & Tadi, P. (2021). Neuroanatomy, Visual Cortex. In *StatPearls*. StatPearls Publishing. http://www.ncbi.nlm.nih.gov/books/NBK482504/

Imuta, K., Henry, J. D., Slaughter, V., Selcuk, B., & Ruffman, T. (2016). Theory of mind and prosocial behavior in childhood: A meta-analytic review. *Developmental Psychology*, *52*(8), 1192–1205. https://doi.org/10.1037/dev0000140

Jagau, S., & van Veelen, M. (2017). A general evolutionary framework for the role of intuition and deliberation in cooperation. *Nature Human Behaviour*, *1*(8), 1–6. https://doi.org/10.1038/s41562-017-0152

Jahng, J., Kralik, J. D., Hwang, D.-U., & Jeong, J. (2017). Neural dynamics of two players when using nonverbal cues to gauge intentions to cooperate during the Prisoner's Dilemma Game. *NeuroImage*, *157*, 263–274. https://doi.org/10.1016/j.neuroimage.2017.06.024

Kaiser, D. A. (2010). Cortical Cartography. *Biofeedback*, *38*(1), 9–12. https://doi.org/10.5298/1081-5937-38.1.9

Kane, M. J., Bleckley, M. K., Conway, A. R. A., & Engle, R. W. (2001). A controlled-attention view of working-memory capacity. *Journal of Experimental Psychology: General*, *130*(2), 169–183. https://doi.org/10.1037/0096-3445.130.2.169

Kanner, L. (1943). Autistic disturbances of affective contact. *Nervous Child*, *2*, 217–250.

Kingsbury, L., & Hong, W. (2020). A Multi-Brain Framework for Social Interaction. *Trends in Neurosciences*, *43*(9), 651–666. https://doi.org/10.1016/j.tins.2020.06.008

Kirchner, W. K. (1958a). Age differences in short-term retention of rapidly changing

information. *Journal of Experimental Psychology*, *55*(4), 352–358.

https://doi.org/10.1037/h0043688

Kirchner, W. K. (1958b). Age differences in short-term retention of rapidly changing

information. *Journal of Experimental Psychology*, *55*(4), 352–358.

https://doi.org/10.1037/h0043688

Klimesch, W. (2012). Alpha-band oscillations, attention, and controlled access to stored

information. *Trends in Cognitive Sciences*, *16*(12), 606–617.

https://doi.org/10.1016/j.tics.2012.10.007

Knight, L. K., Stoica, T., Fogleman, N. D., & Depue, B. E. (2019). Convergent Neural Correlates

of Empathy and Anxiety During Socioemotional Processing. *Frontiers in Human*

Neuroscience, *13*. https://doi.org/10.3389/fnhum.2019.00094

Kok, P., Jehee, J. F. M., & de Lange, F. P. (2012). Less Is More: Expectation Sharpens

Representations in the Primary Visual Cortex. *Neuron*, *75*(2), 265–270.

https://doi.org/10.1016/j.neuron.2012.04.034

Kosslyn, S. M., Thompson, W. L., Klm, I. J., & Alpert, N. M. (1995). Topographical

representations of mental images in primary visual cortex. *Nature*, *378*(6556), 496–498.

https://doi.org/10.1038/378496a0

Koster-Hale, J., & Saxe, R. (2013). Theory of Mind: A Neural Prediction Problem. *Neuron*,

79(5), 836–848. https://doi.org/10.1016/j.neuron.2013.08.020

Kourtis, D., Sebanz, N., & Knoblich, G. (2013). Predictive representation of other people's

actions in joint action planning: An EEG study. *Social Neuroscience*, *8*(1), 31–42.

https://doi.org/10.1080/17470919.2012.694823

Kwaadsteniet, E. W. de, & Dijk, E. van. (2012). A social-psychological perspective on tacit coordination: How it works, when it works, (and when it does not). *European Review of Social Psychology*, *23*(1), 187–223. https://doi.org/10.1080/10463283.2012.718136

Kwaadsteniet, E. W. de, Homan, A. C., Van Dijk, E., & Van Beest, I. (2012). Social information as a cue for tacit coordination. *Group Processes & Intergroup Relations*, *15*(2), 257–271. https://doi.org/10.1177/1368430211410235

L Traverso, Mantini, C., Usai, M., & Viterbori, P. (2015). The Relationship Between Inhibition and Working Memory In Preschoolers: Evidence For Different Inhibitory Abilities. *EAPCogSci*.

Lachaux, J., Rodriguez, E., Martinerie, J., & Varela, F. J. (1999). Measuring phase synchrony in brain signals. *Human Brain Mapping*, *8*(4), 194–208. https://doi.org/10.1002/(SICI)1097-0193(1999)8:4<194::AID-HBM4>3.0.CO;2-C

Leary, M. R. (1983). Social anxiousness: The construct and its measurement. *Journal of Personality Assessment*, *47*(1), 66–75. https://doi.org/10.1207/s15327752jpa4701_8

Leary, M. R., & Kowalski, R. M. (1993). The Interaction Anxiousness Scale: Construct and Criterion-Related Validity. *Journal of Personality Assessment*, *61*(1), 136–146. https://doi.org/10.1207/s15327752jpa6101_10

Lecce, S., & Bianco, F. (2018). Working memory predicts changes in children's theory of mind during middle childhood: A training study. *Cognitive Development*, *47*, 71–81. https://doi.org/10.1016/j.cogdev.2018.04.002

Lecce, S., Bianco, F., Devine, R. T., & Hughes, C. (2017). Relations between theory of mind and executive function in middle childhood: A short-term longitudinal study. *Journal of Experimental Child Psychology*, *163*, 69–86. https://doi.org/10.1016/j.jecp.2017.06.011

Leslie, A. M., Friedman, O., & German, T. P. (2004). Core mechanisms in "theory of mind."

    Trends in Cognitive Sciences, *8*(12), 528–533. https://doi.org/10.1016/j.tics.2004.10.001

Lin, S., Keysar, B., & Epley, N. (2010). Reflexively mindblind: Using theory of mind to interpret

    behavior requires effortful attention. *Journal of Experimental Social Psychology*, *46*(3),

    551–556. https://doi.org/10.1016/j.jesp.2009.12.019

Lindenberger, U., Li, S.-C., Gruber, W., & Müller, V. (2009). Brains swinging in concert:

    Cortical phase synchronization while playing guitar. *BMC Neuroscience*, *10*, 22.

    https://doi.org/10.1186/1471-2202-10-22

Lisha Sun, Ying Liu, & Beadle, P. J. (2005). Independent component analysis of EEG signals.

    Proceedings of 2005 IEEE International Workshop on VLSI Design and Video

    Technology, 2005., 219–222. https://doi.org/10.1109/IWVDVT.2005.1504590

Lu, K., & Hao, N. (2019). When do we fall in neural synchrony with others? *Social Cognitive*

    and Affective Neuroscience, *14*(3), 253–261. https://doi.org/10.1093/scan/nsz012

Luck, S. J. (2014). *An introduction to the event-related potential technique* (Second edition). The

    MIT Press.

Lukasik, K. M., Waris, O., Soveri, A., Lehtonen, M., & Laine, M. (2019). The Relationship of

    Anxiety and Stress With Working Memory Performance in a Large Non-depressed

    Sample. *Frontiers in Psychology*, *10*. https://doi.org/10.3389/fpsyg.2019.00004

Mahy, C. E. V., Moses, L. J., & Pfeifer, J. H. (2014). How and where: Theory-of-mind in the

    brain. *Developmental Cognitive Neuroscience*, *9*, 68–81.

    https://doi.org/10.1016/j.dcn.2014.01.002

Mansouri, F. A., Koechlin, E., Rosa, M. G. P., & Buckley, M. J. (2017). Managing competing goals—A key role for the frontopolar cortex. *Nature Reviews Neuroscience*, *18*(11), 645–657. https://doi.org/10.1038/nrn.2017.111

March, J. G. (1991). Exploration and Exploitation in Organizational Learning. *Organization Science*, *2*(1), 71–87.

Mehta, J., Starmer, C., & Sugden, R. (1994). The Nature of Salience: An Experimental Investigation of Pure Coordination Games. *The American Economic Review*, *84*(3), 658–673.

Meyer, M. L., & Lieberman, M. D. (2012). Social Working Memory: Neurocognitive Networks and Directions for Future Research. *Frontiers in Psychology*, *3*. https://doi.org/10.3389/fpsyg.2012.00571

Mills, K. L., Dumontheil, I., Speekenbrink, M., & Blakemore, S.-J. (2015). Multitasking during social interactions in adolescence and early adulthood. *Royal Society Open Science*, *2*(11), 150117. https://doi.org/10.1098/rsos.150117

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "Frontal Lobe" tasks: A latent variable analysis. *Cognitive Psychology*, *41*(1), 49–100. https://doi.org/10.1006/cogp.1999.0734

Miyake, A., & Shah, P. (Eds.). (1999). *Models of Working Memory: Mechanisms of Active Maintenance and Executive Control* (1st ed.). Cambridge University Press. https://doi.org/10.1017/CBO9781139174909

Montague, P. (2002). Hyperscanning: Simultaneous fMRI during Linked Social Interactions. *NeuroImage*, *16*(4), 1159–1164. https://doi.org/10.1006/nimg.2002.1150

Moran, T. P. (2016). Anxiety and working memory capacity: A meta-analysis and narrative

    review. *Psychological Bulletin*, *142*(8), 831–864. https://doi.org/10.1037/bul0000051

Mu, Y., Guo, C., & Han, S. (2016). Oxytocin enhances inter-brain synchrony during social

    coordination in male adults. *Social Cognitive and Affective Neuroscience*, *11*(12), 1882–

    1893. https://doi.org/10.1093/scan/nsw106

Mutter, B., Alcorn, M. B., & Welsh, M. (2006). Theory of Mind and Executive Function:

    Working-Memory Capacity and Inhibitory Control as Predictors of False-Belief Task

    Performance. *Perceptual and Motor Skills*, *102*(3), 819–835.

    https://doi.org/10.2466/pms.102.3.819-835

Nam, C. S., Choo, S., Huang, J., & Park, J. (2020). Brain-to-Brain Neural Synchrony During

    Social Interactions: A Systematic Review on Hyperscanning Studies. *Applied Sciences*,

    10(19), 6669. https://doi.org/10.3390/app10196669

Nozawa, T., Sakaki, K., Ikeda, S., Jeong, H., Yamazaki, S., Kawata, K. H. dos S., Kawata, N. Y.

    dos S., Sasaki, Y., Kulason, K., Hirano, K., Miyake, Y., & Kawashima, R. (2019). Prior

    physical synchrony enhances rapport and inter-brain synchronization during subsequent

    educational communication. *Scientific Reports*, *9*(1), 12747.

    https://doi.org/10.1038/s41598-019-49257-z

Obeso, I., Robles, N., Muñoz-Marrón, E., & Redolar-Ripoll, D. (2013). Dissociating the Role of

    the pre-SMA in Response Inhibition and Switching: A Combined Online and Offline

    TMS Approach. *Frontiers in Human Neuroscience*, *7*.

    https://doi.org/10.3389/fnhum.2013.00150

Oei, N. Y. L., Everaerd, W. T. A. M., Elzinga, B. M., Well, S. van, & Bermond, B. (2006).

    Psychosocial stress impairs working memory at high loads: An association with cortisol

levels and memory retrieval. *Stress*, *9*(3), 133–141.

    https://doi.org/10.1080/10253890600965773

Owen, A. M., McMillan, K. M., Laird, A. R., & Bullmore, E. (2005). N-back working memory

    paradigm: A meta-analysis of normative functional neuroimaging studies. *Human Brain*

    Mapping, *25*(1), 46–59. https://doi.org/10.1002/hbm.20131

Pellicano, E. (2007). Links between theory of mind and executive function in young children

    with autism: Clues to developmental primacy. *Developmental Psychology*, *43*(4), 974–

    990. https://doi.org/10.1037/0012-1649.43.4.974

Perner, J., & Lang, B. (1999). Development of theory of mind and executive control. *Trends in*

    Cognitive Sciences, *3*(9), 337–344. https://doi.org/10.1016/S1364-6613(99)01362-5

Petit, L., Courtney, S. M., Ungerleider, L. G., & Haxby, J. V. (1998). Sustained activity in the

    medial wall during working memory delays. *The Journal of Neuroscience*, *18*(22), 9429–

    9437.

Petrashek, A. R., & Friedman, O. (2011). The signature of inhibition in theory of mind:

    Children's predictions of behavior based on avoidance desire. *Psychonomic Bulletin &*

    Review, *18*(1), 199–203. https://doi.org/10.3758/s13423-010-0036-y

Pineda-Alhucema, W., Aristizabal, E., Escudero-Cabarcas, J., Acosta-López, J. E., & Vélez, J. I.

    (2018). Executive Function and Theory of Mind in Children with ADHD: A Systematic

    Review. *Neuropsychology Review*, *28*(3), 341–358. https://doi.org/10.1007/s11065-018-

    9381-9

Polich, J. (2007). Updating P300: An integrative theory of P3a and P3b. *Clinical*

    Neurophysiology, *118*(10), 2128–2148. https://doi.org/10.1016/j.clinph.2007.04.019

Polich, J. (2011). *Neuropsychology of P300*. Oxford University Press.

    https://doi.org/10.1093/oxfordhb/9780195374148.013.0089

Pollmann, S., & von Cramon, D. Y. (2000). Object working memory and visuospatial processing:

    Functional neuroanatomy analyzed by event-related fMRI. *Experimental Brain Research*,

    133(1), 12–22. https://doi.org/10.1007/s002210000396

Premack, D., & Woodruff, G. (1978). Does the chimpanzee have a theory of mind? *Behavioral*

    and Brain Sciences, *1*(4), 515–526. https://doi.org/10.1017/S0140525X00076512

Qureshi, A. W., & Monk, R. L. (2018). Executive function underlies both perspective selection

    and calculation in Level-1 visual perspective taking. *Psychonomic Bulletin & Review*,

    25(4), 1526–1534. https://doi.org/10.3758/s13423-018-1496-8

R Core Team. (2020). *R: A Language and Environment for Statistical Computing* (4.0.2)

    [Computer software]. R Foundation for Statistical Computing. https://www.R-project.org/

Raja Beharelle, A., Polanía, R., Hare, T. A., & Ruff, C. C. (2015). Transcranial Stimulation over

    Frontopolar Cortex Elucidates the Choice Attributes and Neural Mechanisms Used to

    Resolve Exploration-Exploitation Trade-Offs. *The Journal of Neuroscience: The Official*

    Journal of the Society for Neuroscience, *35*(43), 14544–14556.

    https://doi.org/10.1523/JNEUROSCI.2322-15.2015

Rand, D. G. (2016). Cooperation, Fast and Slow: Meta-Analytic Evidence for a Theory of Social

    Heuristics and Self-Interested Deliberation. *Psychological Science*.

    https://doi.org/10.1177/0956797616654455

Rand, D. G., & Nowak, M. A. (2013). Human cooperation. *Trends in Cognitive Sciences*, *17*(8),

    413–425. https://doi.org/10.1016/j.tics.2013.06.003

Redcay, E., & Schilbach, L. (2019). Using second-person neuroscience to elucidate the

    mechanisms of social interaction. *Nature Reviews. Neuroscience*, *20*(8), 495–505.

    https://doi.org/10.1038/s41583-019-0179-4

Reinero, D. A., Dikker, S., & Van Bavel, J. J. (2021). Inter-brain synchrony in teams predicts

    collective performance. *Social Cognitive and Affective Neuroscience*, *16*(1–2), 43–57.

    https://doi.org/10.1093/scan/nsaa135

Resches, M., & Pérez Pereira, M. (2007). Referential communication abilities and Theory of

    Mind development in preschool children. *Journal of Child Language*, *34*(1), 21–52.

    https://doi.org/10.1017/s0305000906007641

Riddle, J., Scimeca, J. M., Cellier, D., Dhanani, S., & D'Esposito, M. (2020). Causal Evidence

    for a Role of Theta and Alpha Oscillations in the Control of Working Memory. *Current

    Biology*, *30*(9), 1748-1754.e4. https://doi.org/10.1016/j.cub.2020.02.065

Roxβnagel, C. (2000). Cognitive load and perspective-taking: Applying the automatic-controlled

    distinction to verbal communication. *European Journal of Social Psychology*, *30*(3),

    429–445. https://doi.org/10.1002/(SICI)1099-0992(200005/06)30:3<429::AID-

    EJSP3>3.0.CO;2-V

Sauseng, P., Klimesch, W., Heise, K. F., Gruber, W. R., Holz, E., Karim, A. A., Glennon, M.,

    Gerloff, C., Birbaumer, N., & Hummel, F. C. (2009). Brain oscillatory substrates of visual

    short-term memory capacity. *Current Biology: CB*, *19*(21), 1846–1852.

    https://doi.org/10.1016/j.cub.2009.08.062

Saxe, R., & Baron-Cohen, S. (2006). Editorial: The neuroscience of theory of mind. *Social

    Neuroscience*, *1*(3–4), 1–9. https://doi.org/10.1080/17470910601117463

Schelling, T. C. (1960). *The Strategy of Conflict*. Harvard University Press.

Schneider, D., Lam, R., Bayliss, A. P., & Dux, P. E. (2012). Cognitive Load Disrupts Implicit

Theory-of-Mind Processing. *Psychological Science*, *23*(8), 842–847. JSTOR.

Sebanz, N., Bekkering, H., & Knoblich, G. (2006). Joint action: Bodies and minds moving

together. *Trends in Cognitive Sciences*, *10*(2), 70–76.

https://doi.org/10.1016/j.tics.2005.12.009

Sidera, F., Perpiñà, G., Serrano, J., & Rostan, C. (2018). Why Is Theory of Mind Important for

Referential Communication? *Current Psychology (New Brunswick, N.j.)*, *37*(1), 82–97.

https://doi.org/10.1007/s12144-016-9492-5

Sugden, R. (1995). A Theory of Focal Points. *The Economic Journal*, *105*(430), 533–550.

https://doi.org/10.2307/2235016

Sweet, L. H. (2011). N-Back Paradigm. In J. S. Kreutzer, J. DeLuca, & B. Caplan (Eds.),

Encyclopedia of Clinical Neuropsychology (pp. 1718–1719). Springer New York.

https://doi.org/10.1007/978-0-387-79948-3_1315

Tatar, Z. B., & Cansız, A. (2020). Executive function deficits contribute to poor theory of mind

abilities in adults with ADHD. *Applied Neuropsychology: Adult*, *0*(0), 1–8.

https://doi.org/10.1080/23279095.2020.1736074

Todd, A. R., & Galinsky, A. D. (2014). Perspective-Taking as a Strategy for Improving

Intergroup Relations: Evidence, Mechanisms, and Qualifications. *Social and Personality

Psychology Compass*, *8*(7), 374–387. https://doi.org/10.1111/spc3.12116

Tognoli, E., Lagarde, J., DeGuzman, G. C., & Kelso, J. A. S. (2007). The phi complex as a

neuromarker of human social coordination. *Proceedings of the National Academy of

Sciences*, *104*(19), 8190–8195.

Tong, F. (2013). Imagery and visual working memory: One and the same? *Trends in Cognitive Sciences*, *17*(10), 489–490. https://doi.org/10.1016/j.tics.2013.08.005

Toppi, J., Borghini, G., Petti, M., He, E. J., Giusti, V. D., He, B., Astolfi, L., & Babiloni, F. (2016). Investigating Cooperative Behavior in Ecological Settings: An EEG Hyperscanning Study. *PLOS ONE*, *11*(4), e0154236. https://doi.org/10.1371/journal.pone.0154236

Tsai, C.-C., Kuo, W.-J., Jing, J.-T., Hung, D. L., & Tzeng, O. J.-L. (2006). A common coding framework in self–other interaction: Evidence from joint action task. *Experimental Brain Research*, *175*(2), 353–362. https://doi.org/10.1007/s00221-006-0557-9

Usami, K., Matsumoto, R., Kunieda, T., Shimotake, A., Matsuhashi, M., Miyamoto, S., Fukuyama, H., Takahashi, R., & Ikeda, A. (2013). Pre-SMA actively engages in conflict processing in human: A combined study of epicortical ERPs and direct cortical stimulation. *Neuropsychologia*, *51*(5), 1011–1017. https://doi.org/10.1016/j.neuropsychologia.2013.02.002

van der Meer, L., Groenewold, N. A., Nolen, W. A., Pijnenborg, M., & Aleman, A. (2011). Inhibit yourself and understand the other: Neural basis of distinct processes underlying Theory of Mind. *NeuroImage*, *56*(4), 2364–2374. https://doi.org/10.1016/j.neuroimage.2011.03.053

van Dijk, E., de Kwaadsteniet, E. W., & De Cremer, D. (2009). Tacit coordination in social dilemmas: The importance of having a common understanding. *Journal of Personality and Social Psychology*, *96*(3), 665–678. https://doi.org/10.1037/a0012976

Van Huyck, J. B., Wildenthal, J. M., & Battalio, R. C. (2002). Tacit Cooperation, Strategic Uncertainty, and Coordination Failure: Evidence from Repeated Dominance Solvable

Games. *Games and Economic Behavior*, *38*(1), 156–175.

https://doi.org/10.1006/game.2001.0860

Van Lange, P. A. M., De Cremer, D., Van Dijk, E., & Van Vugt, M. (2007). Self-interest and

beyond: Basic principles of social interaction. In *Social psychology: Handbook of basic

principles, 2nd ed* (pp. 540–561). The Guilford Press.

van Leeuwen, J., Smeets, J. B. J., & Belopolsky, A. V. (2019). Forget binning and get SMART:

Getting more out of the time-course of response data. *Attention, Perception, &

Psychophysics*, *81*(8), 2956–2967. https://doi.org/10.3758/s13414-019-01788-3

van Vugt, M. K., Schulze-Bonhage, A., Litt, B., Brandt, A., & Kahana, M. J. (2010).

Hippocampal Gamma Oscillations Increase with Memory Load. *The Journal of

Neuroscience*, *30*(7), 2694–2699. https://doi.org/10.1523/JNEUROSCI.0567-09.2010

van Vugt, M. K., Simen, P., Nystrom, L. E., Holmes, P., & Cohen, J. D. (2012). EEG Oscillations

Reveal Neural Correlates of Evidence Accumulation. *Frontiers in Neuroscience*, *6*.

https://doi.org/10.3389/fnins.2012.00106

Vergauwe, E., Dewaele, N., Langerock, N., & Barrouillet, P. (2012). Evidence for a central pool

of general resources in working memory. *Journal of Cognitive Psychology*, *24*(3), 359–

366. https://doi.org/10.1080/20445911.2011.640625

Wainer, H., Gessaroli, M., & Verdi, M. (2006). Visual Revelations. *CHANCE*, *19*(1), 49–52.

https://doi.org/10.1080/09332480.2006.10722771

Ward, L. M. (2003). Synchronous neural oscillations and cognitive processes. *Trends in

Cognitive Sciences*, *7*(12), 553–559. https://doi.org/10.1016/j.tics.2003.10.012

Wessel, J. R., & Aron, A. R. (2015). It's not too late: The onset of the frontocentral P3 indexes successful response inhibition in the stop-signal paradigm. *Psychophysiology*, *52*(4), 472–480. https://doi.org/10.1111/psyp.12374

Wickramarachi, P. (2003). Effects of windowing on the spectral content of a signal. *Sound and Vibration*, *37*, 10–11.

Wimmer, H., & Perner, J. (1983). Beliefs about beliefs: Representation and constraining function of wrong beliefs in young children's understanding of deception. *Cognition*, *13*(1), 103–128. https://doi.org/10.1016/0010-0277(83)90004-5

Yun, K., Watanabe, K., & Shimojo, S. (2012). Interpersonal body and neural synchronization as a marker of implicit social interaction. *Scientific Reports*, *2*(1), 959. https://doi.org/10.1038/srep00959

Zainal, N. H., & Newman, M. G. (2018). Worry amplifies theory-of-mind reasoning for negatively valenced social stimuli in generalized anxiety disorder. *Journal of Affective Disorders*, *227*, 824. https://doi.org/10.1016/j.jad.2017.11.084

Zaki, J., & Mitchell, J. P. (2013). Intuitive Prosociality. *Current Directions in Psychological Science*, *22*(6), 466–470. https://doi.org/10.1177/0963721413492764

Zhang, M., Jia, H., & Zheng, M. (2020). Interbrain Synchrony in the Expectation of Cooperation Behavior: A Hyperscanning Study Using Functional Near-Infrared Spectroscopy. *Frontiers in Psychology*, *11*. https://doi.org/10.3389/fpsyg.2020.542093