The role of Working Memory in Theory of Mind: A behavioral study coupled with EEG hyperscanning.

Bachelor's Project Thesis

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Abstract: People use Theory of Mind (ToM) to create models of other's thoughts and actions in order to anticipate and coordinate better. For example, when playing volleyball you think about how your teammate is going to pass you the ball in order to be ready for this pass. In this study the role of working memory (WM) in ToM related problems is studied using a tacit coordination task. WM load was manipulated by means of an N-back task to study how it affects performance on the task. A significant difference in accuracy was found between low and high WM load conditions, which may suggest that ToM related tasks use WM resources. One neural mechanism that might explain this coordination without communication is the synchronization between brain activity of two people. During our experiment EEG hyperscanning was used to record brain activity in participants simultaneously and ultimately to analyse the Inter Brain Synchrony (IBS) between participants. Combining the IBS scores with the behavioral results helps us to better understand how coordination between individuals is achieved.

1 Introduction

In daily life we are often faced with problems that require us to reason about others' actions. Some of these problems go a step further and require us to reason about other's intentions, beliefs and knowledge. Examples of such problems are participating in traffic on a bike, playing a sport in a team or any social interaction. This reasoning about others' mental states is called Theory of Mind (ToM). Representations of others' minds do not have to be in line with the world or the subjects own thoughts, but are projections of our own mind. Using ToM we can anticipate what others will do and choose actions based on that; coordination. In order to use ToM we need sensory input and some domain general brain functions, one of which might be working memory (WM). Some studies (Maehara & Saito, 2011; Meyer & Lieberman, 2016) have shown that by increasing WM load, ToM performance decreases which suggests that WM is indeed a vital keystone of ToM. In addition, the development of WM and ToM in children is extensively studied and some studies found that WM and ToM development were positively correlated (Lecce & Bianco, 2018; He et al., 2019). This is in conflict with early research on ToM (Baron-Cohen, 1995; Fodor, 1992; Leslie, 1994) which often explained the source of ToM to be modular and not using general resources like WM. In recent years social and cognitive psychology research consider the resources needed for ToM to be a collaboration between modular and general ones (Leslie et al., 2004, 2005; McKinnon & Moscovitch, 2007). This would imply that ToM is not a mechanism on its own but an emergent feature of the brain instead.

Working memory can be considered as an executive function of the brain. Executive functions modulate the activity of other cognitive functions in a goal directed way. They can occur consciously, mediated by thoughtful processing, or unconsciously. WM is one executive function that temporarily maintains and manipulates information that is not currently available to senses. Some studies argue that sensory information is stored in the same brain areas that process these sensory stimuli (Rose, 2020) and that WM is used to access and use this information. Most research on executive functions has implicated the prefrontal cortex to have a large role in executive functions like WM. This is mostly because patients with brain damage in this area almost always have severe impairments in performing complex tasks and understanding concepts that require more than simple input processing. Despite this evidence suggesting that executive functions are contingent on the prefrontal cortex, this is not the only area responsible for these functions. The leading idea in the field of the cognitive sciences is that executive functions depend on a larger set of brain regions including the prefrontal cortex, the parietal cortex, the basal ganglia and possibly other regions (Purves et al., 2018). Because WM depends on a lot of different brain areas it is safe to assume that it is relevant to many processes that constitute ToM.

A neural phenomenon that may be of relevance to ToM is inter-brain synchronization (IBS). This is measured by the degree to which brain signals at certain intervals or time points are synchronized. When people coordinate with each other, they essentially have a representation of their own intentions and beliefs, but also a representation about the others' intentions and beliefs. This second representation is created using ToM and is maintained by WM. During a coordination task, both parties need to update their representations in order to predict what the other person will do and anticipate on that. This would mean that when coordination is successful, both parties likely made similar updates to the representations in their brains. It would make sense that IBS is greater when people make similar updates in for example WM, compared to when they make very different updates (in cases where coordination fails) because similar updates would implicate similar brain activity. This is backed up by studies that show that functional links in the brain appear across participants during cooperation but not during simultaneous individual tasks that are identical (Sinha et al., 2016; Balconi & Vanutelli, 2018). This suggests that the degree of IBS could predict how well people are able to use ToM.

There are several ways to measure someone's ability to use ToM, most of which are coordination tasks. Some coordination tasks that have been used for a long time are game theory tasks such as the well known prisoners dilemma. One branch of game theory is repeated game tasks. These tasks usually use a well documented 2 person game like the prisoners dilemma as a base game. These base games are played repeatedly such that subjects form conventions about the others' choices and as a cause they often reach Nash equilibriums if there are any (Mehta et al., 1994). This would imply that subjects form a representation about the other subjects future choices using ToM.

Using a coordinated ToM task we wish to investigate the role of WM on ToM and see if the degree of IBS can predict the performance on the task. The task is largely based on a task developed by Alberti and colleagues (Alberti et al., 2012) in which two participants simultaneously need to choose images from a set of images and get feedback based on the similarity to what the other participant chose. Sets of images are not repeated, so the idea is that participants need to create abstract conventions in order to coordinate better. In addition we manipulate WM load by an n-back task. For a more theoretical and motivational background of the task itself I refer to the paper by Alberti and colleagues (Alberti et al., 2012). During the whole experiment EEG signals from the participants were recorded so that the degree of IBS at certain time points can be analyzed. These time points represent key moments at which WM should be updated in both participants. If coordination performance is better we expect to see greater IBS because the updating in both individuals would be similar. This leads us to our first research question: "Does a high working memory load negatively affect the performance on a coordinated ToM task?". We believe that WM plays a key role in the creation of ToM related thoughts and actions so naturally we think that performance will be worse in the high load condition compared to the low load condition due to competing resources. The second research question we wish to answer with this experiment is: "Can the degree of inter brain-synchronization positively predict the performance on a coordinated ToM task?". We believe that this is possible and that greater IBS will correlate with higher performance on both low and high WM load conditions.

2 Methods

2.1 Subjects

43 pairs of subjects were recruited of which most were international students studying in Groningen. Subjects ranged in age from 19 to 36 with a mean age of 23.52 and a SD of 3.99. 8 Pairs were male and 35 pairs were female. Subjects were coupled in pairs of the same gender and were all unfamiliar with each other prior to the experiment. Only same-sex coupling was studied because of gender gender specific coordination differences found in previous studies (Baker et al., 2016; Cheng et al., 2015). The following inclusion criteria were selected for the recruitment of subjects: normal or corrected-to-normal visual acuity (no color blindness) and right manual dominance. Subjects were paid 8 euros per hour with an additional 0-4 euros based on their performance, a session usually took 2 hours including placing and removing the EEG equipment. Before each session the subjects were given a verbal overview of the study and an informed consent form. After they signed the form they proceeded to fill in a questionnaire consisting of question related to their use of ToM (see Appendix A). 20 subjects were excluded from the EEG analysis because of incomplete EEG data or data lost during processing.

2.2 Procedure

When the subjects were finished with the questionnaires, the EEG equipment was applied in a standardized manner. The distance between the nasion and the inion was measured and the A32 electrode (see figure 2.3) was positioned exactly in the middle. Four external electrodes were used to filter out eye movement and blinks, they were placed to the outer side of the eyes and above and below the left eye. Additionally two electrodes were placed on the mastoids behind the ears to use for referencing. There is little to no brain signal recorded at the mastoids, but they are relatively close to the other electrodes. This makes them a good place to use for referencing since signals recorded in those electrodes definitely do not come from the brain. Before the experiment began, all channels were inspected and noisy channels were fixed by either applying more gel or switching out the electrode for a new one.

Each session consisted of two same-sex subjects doing the task in the same room, separated by a closet in between. The matching of the subjects was done at random, besides the same-gender criterion. The subjects got the instructions not to communicate via speech or any other methods from the experimenter and got further written instructions shown to them on the screen (see Appendix B). Before the start of the session there were two practice sessions. One for practicing the number task and one for practicing the image task. These practice sessions served to familiarize the subjects with the image task and the time available in the number task.

2.3 Design

This experiment uses a 2x2 design where WM load and stimulus type both have two conditions; low/high WM load x shape/color simuli. We manipulated WM load by using two different number tasks in between the main image tasks, creating a low and high WM load condition. In the high WM load condition subjects were shown a number before a trial which they needed to keep in mind. Two trials later they were shown a number between 0-9 on the screen again and needed to decide whether that number was the same or different to the number from 2 trials ago. The numbers shown after two trials were controlled and had a 33% chance of being the same number that they had to keep in mind. This was done to keep subjects from getting a 50% accuracy by randomly guessing. In the low WM load condition subjects were shown a number between 0-9 after each trial and need to decide whether they are odd or even. Both of these number tasks were time restricted by 2495ms, this limit was chosen based on similar studies using a tacit coordination task.

There were two types of stimuli used so that the conventions that the subjects formed in the first half of the experiment could not be carried over to the second part. Both stimuli types consisted of a grid of 64 squares that were either fully colored, or contained an abstract shape. The stimuli were both randomly generated and presented to the subjects in a random order. Examples of the stimuli used are shown in figure 2.1 and figure 2.2.

One session of the experiment consisted of two

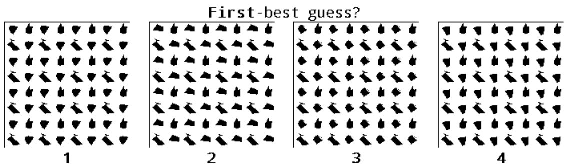

Figure 2.1: Shape stimuli - first guess presentation.

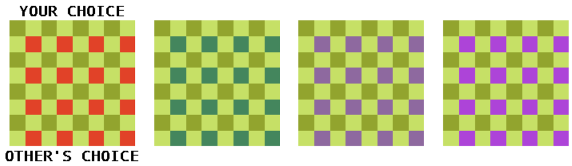

Figure 2.2: Color stimuli - correct trial, both first guesses were the left-most image.

parts that both contained 90 trials. Both parts had a different combination of WM load and stimuli type. An example condition would be shape stimuli with a high WM load.

In image trials the subjects had two guesses, their first and second-best guess for which there was no time limit. A guess implied a chance to choose the same image as the other subject, two guesses were used to give subjects more information so to understand the other's guesses better. Only the first-best guess was used for the analyses. The result of the first guess was only shown after both subjects had entered their first and second guess. This was because previous research indicated that this positively affected learning performance and invoked greater IBS (Balconi & Vanutelli, 2018). Their own choice was indicated by the text "YOUR CHOICE" and the other's choice was indicated by the text "OTHER'S CHOICE". The entire experiment was controlled by the subjects using a keyboard.

Subjects were instructed to base their choices on features of the images instead of their position on the screen and to pay an equal amount of attention to both the number and the image tasks. Subjects were aware that image positions could be different for both of them. After the experiment had ended a debriefing form was filled out containing questions about the strategies they used.

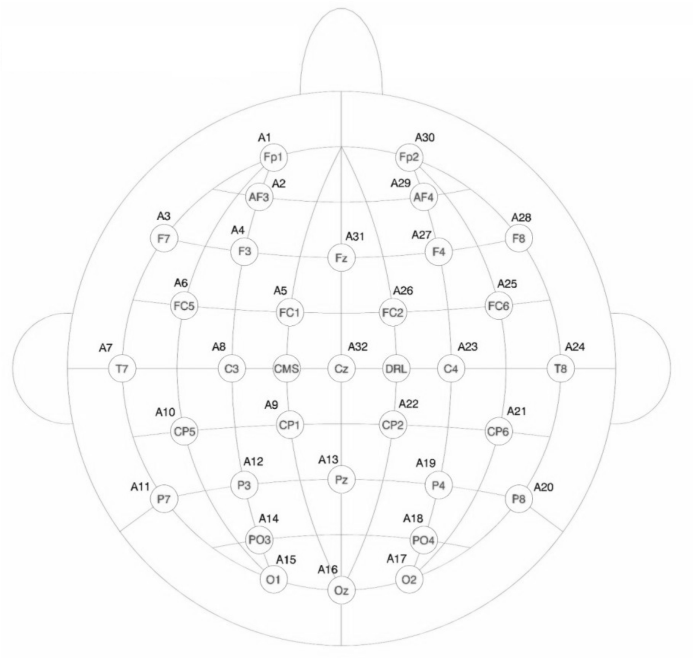

Figure 2.3: Layout of the electrodes on the head.

2.4 EEG Recording and Data Preprocessing

Two 32-channel EEG systems were used for the EEG signal recording with an additional 6 'external' electrodes used for filtering out noise. The 32 electrodes were placed on the subjects scalps using two ElectroCaps with 32 holes. The layout of the electrodes is shown in figure 2.3. Two external electrodes were placed on the mastoids behind the ears, two were placed horizontally next to the eyes and two were placed above and below the left eye. The electrodes around the eyes are mainly for filtering out eye blinks and the ones behind the ears are reference electrodes since no brain signal should be coming out of these areas.

The data was split up into two sets, one for each subject. After this, the data of each subject was re-referenced to the average of the electrodes on the mastoids separately and then padded to prevent edge artifacts. Following this, high and low pass filters were applied to filter out any data outside of the 0.1Hz - 50Hz range. After this step, manual inspection of the channels was done to identify any bad channels that were too noisy.

After filtering the data was split into trials and then detrended. Following this the trials were manually inspected for rejection due to obvious noise. Then an independent component analysis was run to identify specific noise components that cause a high amount of variance in the data. Components are manually inspected and possibly removed based on amount of variance caused and localization. All of these pre-processing steps were done in MatLab using the Fieldtrip package, for more information see ***Fieldtrip package***.

2.5 Analysis

2.5.1 Behavioral

To investigate whether WM load has a significant effect on mean accuracy we created two mixed linear effects models which we compared using a likelihood ratio test. The null model contained an intercept, the stimulus type as a fixed effect, the subject number as a random effect and the accuracy as the dependant variable. The full model also contained the WM load condition as fixed effect. An interaction variable between WM load and stimulus type did not produce a better fitting model so this variable was not included.

To test the significance of the stimulus type, two similar mixed linear effects models were created. The null model contained the same variables as the previous null model, but with WM load condition as a fixed effect instead of stimulus type. The full model included stimulus type as a predictor of accuracy. Again we compared the null model to the full model with a likelihood ratio test.

2.5.2 Interbrain synchronization

Our analysis on the EEG data is similar to the analysis on the behavioral data, we made multiple linear mixed effects models and compared them using a likelihood ratio test. The mean IBS in a trial was introduced as a variable which reflects the mean IBS between two subjects within the prefrontal brain area. The beginning of each image trial functioned as the trigger point where we measure IBS. These are the moments where we would expect the degree of IBS to be higher, because when subjects see an image they immediately need to think about what their partner will choose. We calculated the IBS using the phase locking value (PLV) measure, which reflects the mean coherence of the phases. The PLV is calculated by using formula 2.1.

$$PLV_t = \frac{1}{T}\left|\sum_{n=1}^{T} exp(j\phi(t,n))|\right|, j = \sqrt{-1} \quad (2.1)$$

Where t is time, T is the number of timesteps in a trial and $\phi(t, n)$ is the phase difference at time t and timestep n. The PLV's are averaged to get one value per trial for each pair of electrodes.

Only data from the frontal electrodes Fp1, Fp2, AF3, AF4, F7, F3, Fz, F4 and F8 was used to calculate the PLV, as we are particularly interested in the IBS in the prefrontal cortex. We used frequencies from the alpha band (9Hz - 14Hz) because previous studies found that IBS in the alpha band frequencies is associated with coordination (Hu et al., 2018; Sinha et al., 2016). All the raw data was looked at and strong artifacts such as head movement or other unclear noise were manually removed. Channels that produced a lot of noise were interpolated using the neighbouring channels and trials that included only noise were removed. After manually removing obvious irregular noise, an independent component analysis was run to identity common components such as eye blinks, that cause a lot of variance in the data. These components were manually inspected and rejected if necessary.

We set up multiple linear mixed effects models in order to test whether IBS has an influence of accuracy, or the other way around. In all these models we controlled for stimulus type by adding it as a fixed effect. We also controlled for the difference between subject pairs by adding session number as a random effect. When the predictor and outcome variables are not related to the WM load we added this as a fixed effect to control for the variance caused by the number trials.

3 Results

3.1 Behavioral results

First we look at the average accuracy between WM load conditions, and we see that there is a higher mean accuracy of the first guess in the low WM load condition compared to the high WM load con-

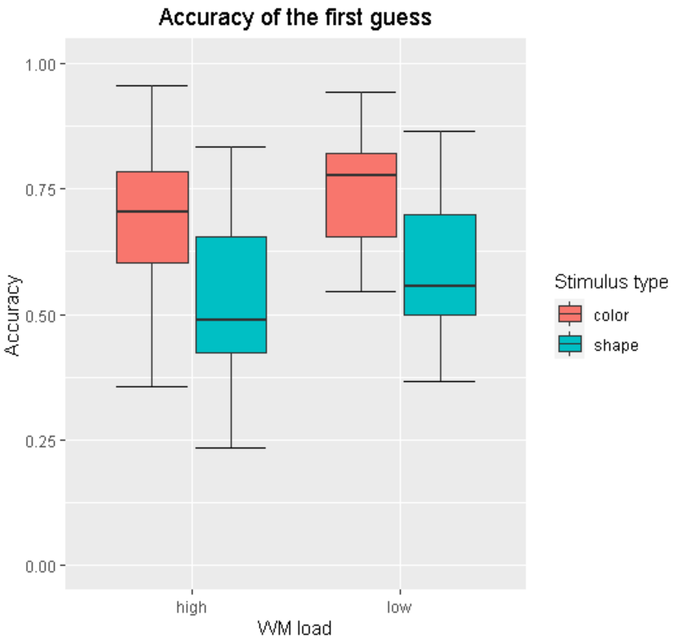

Figure 3.1: Accuracy in all four combinations of WM load and stimuli.

dition. In the low WM load condition the mean percentage of correct guesses was 66.905% whereas in the high WM load condition this was 61.918%.

Condition	Correct	Incorrect	Total	% Correct
Low	2529	1251	3780	66.905
High	2395	1473	3869	61.918

Table 3.1: Results of the first guess.

Secondly we look at how the average accuracy differs between the two stimulus types. We see that the mean accuracy in the color condition is 71.356% compared to 57.063% in the shape condition. Figure 3.1 gives an overview of the accuracy in all four conditions of the experiment. Here we see that regardless of stimulus type, the mean accuracy is higher in the low WM load conditions. Additionally the data is slightly skewed to the left for color stimuli and slightly skewed to the right for shape stimuli.

We compared a model that included WM load as a fixed effect to a model that did not and found that the model including WM load produced a lower AIC score (-88.341 for the full model and -86.273 for the null model). A likelihood ratio test suggested that the model including WM load was a significantly better fit with $X^2(1) = 4.0679, p = 0.04371$. Next we also compared a model including stimulus type as a fixed effect to a model without stimulus type. The model with stimulus type included produced an AIC score of -88.341 compared to an AIC score of -65.113 for the model without stimulus type. Again we ran a likelihood ratio test which suggested a significantly better fit with $X^2(1) = 25.228, p = 5.094e^{-07}$. The results of these tests suggest that both WM load and stimulus type are significant predictors of accuracy.

3.2 Inter brain synchronization results

First of all we took a look at the degree of IBS in correct and in incorrect trials to see if there will be higher IBS during correct trials, which could mean that there was better coordination in those trials. Figure 3.2 shows the the mean IBS and the SE for incorrect and correct trials. The mean IBS in incorrect trials (0.233) is slightly higher than in correct trials (0.231). To test whether this difference is significant we compared a model that included accuracy as a predictor variable to a null model that did not. The full model produced a lower AIC score (-13938) than the null model (-13937) but the fit was not significantly better: $X^2(2) = 4.9478, p = 0.08426$. This suggests that IBS was not greater in correct trials which could imply that better coordination does not produce a greater degree of IBS.

To further explore the relation between accuracy and IBS we plotted the mean IBS and mean accuracy per session against each other in figure 3.3. Each point in this graph represents a session. The y-axis represents the mean IBS over a whole session and the x-axis represents the mean accuracy of the two subjects combined over a whole session. We see a trend line where the mean IBS slightly increases as the mean accuracy goes, up but this is not a significant relation. A Pearson correlation test resulted in r(21) = 0.11, p = 0.081 which suggests that the IBS scores and the accuracy are not correlated. This would imply that pairs that coordinate better do not produce a higher degree of IBS. Because subjects might learn to coordinate throughout sessions, looking at only the mean IBS

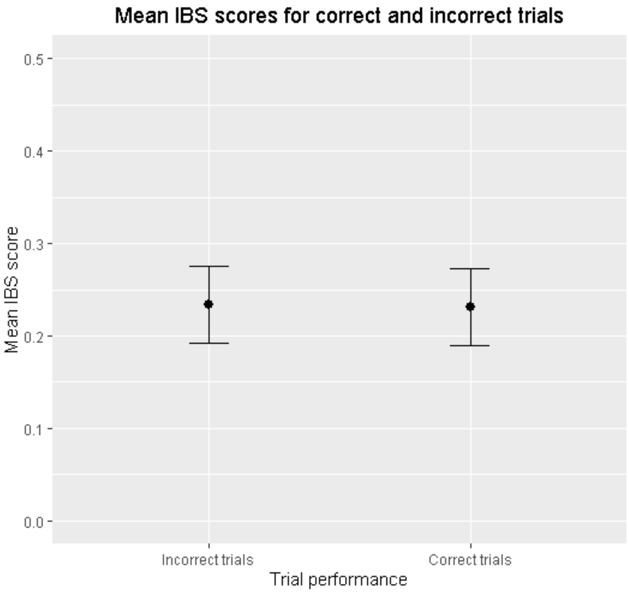

Figure 3.2: Mean IBS per correctness.

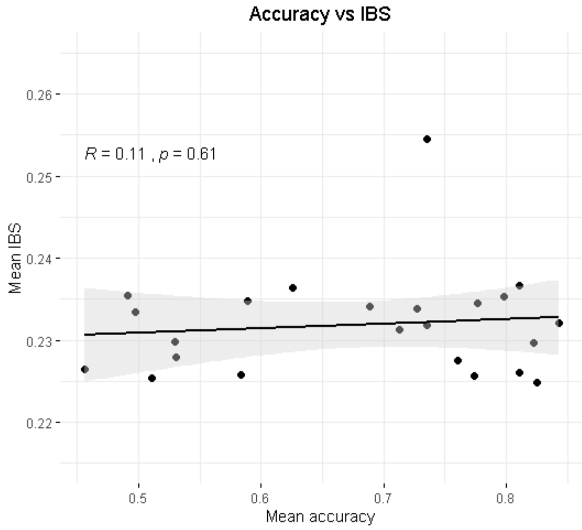

Figure 3.3: Mean accuracy and IBS-scores per session.

and accuracy over the sessions as a whole might not be the most relevant way of looking at this data. Therefore we will also look at how the IBS changes within sessions.

To look at how the average IBS changes during a session the data was binned into five bins. Each bin represents a different set of trials within the session. Bin 1 contains trials 1-35, the second bin contains the trials 36-71, the third bin contains trials 72-107, the fourth bin contains trials 108-143 and the fifth bin contains trials 144-180. For each session, the mean IBS was calculated per bin after which the means of all sessions were combined to compute the mean IBS per bin of sessions. In figure 3.4 we see that the average IBS score does not seem to increase during a session. To further analyse this we compared another linear mixed effects model that included bin as a predictor to a model that did not. A likelihood ratio test resulted in $X^2(1) = 0.0117, p = 0.9138$ suggesting that the IBS does not change significantly during a session. We compared to similar models to see whether accuracy did change during a session. We found that a model that included bin as a predictor for accuracy produced a lower AIC score (-130.14) compared to the model that did not (-131.13). However, the fit of the full model was not significantly better with $X^2(1) = 1.0131, p = 0.3142$. The results of these tests imply that participants did not improve their coordination during a session.

In order to further explore the relation between WM load and IBS, we plotted the average IBS in the four conditions in figure 3.5. We see that the standard error varies somewhat between conditions but the there is no clear difference in means between the conditions. We compared a model that included WM load as a predictor variable for IBS to a model that did not. We found that the model including WM load produced a higher AIC score (-13937 for the full model and -13938 for the null model). The fit of the null model did not produce a significantly better fit with $X^2(1) = 1.0318, p = 0.3097$. This would imply that WM load has no significant effect on IBS and that the resources used by WM are not needed to create higher degrees of IBS.

Lastly we will look at how IBS and accuracy directly affect each other to see if the degree of IBS can predict the accuracy of the first guess. We compared another two models, one with IBS as a predictor for accuracy and one with a random intercept as a predictor. The null model without IBS as a predictor produced a lower AIC score (-331.01) than the full model (-331.00), but did not produce a significantly better fit: $X^2(1) = 1.976, p = 0.1598$.

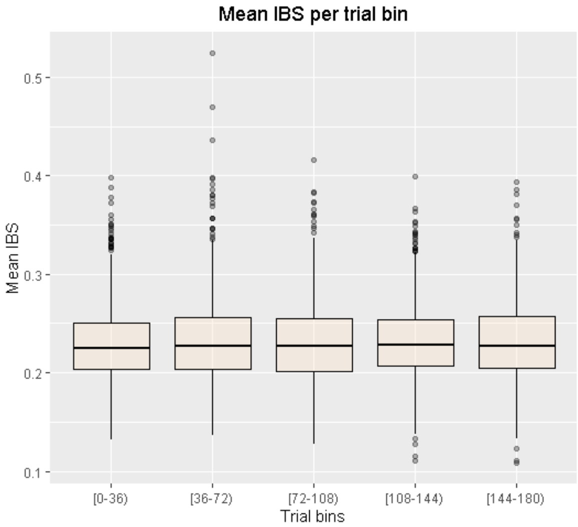

Figure 3.4: Mean IBS-scores of all sessions, divided into trial bins.

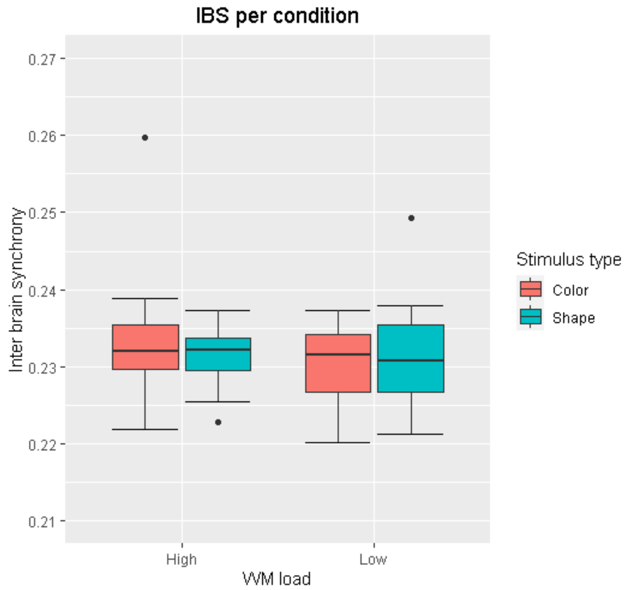

Figure 3.5: IBS in all four combinations of WM load and stimuli.

This suggests that IBS cannot be used to predict the accuracy of the first guess.

4 Discussion

4.1 Conclusions

The primary goal of this study was to build on the findings of Maehara & Saito (2011) by showing that WM load can affect coordination on a coordinated ToM task. We found a higher mean accuracy on the first guess in the low WM load condition compared to the high WM load condition, irrespective of the stimulus type used. By comparing a model that included WM load as a predictor for accuracy to a model that did not, we found that WM load has a significant effect on the accuracy. Specifically, accuracy in the high WM load condition was significantly lower than accuracy in the low WM load condition. This suggests that WM and ToM do indeed use shared resources from the brain.

The secondary goal of our experiment was to see if we could predict the accuracy of the first guess in a trial based on the degree of IBS in that trial. We predicted that a higher degree of IBS would correlate with a higher accuracy because a higher degree of IBS could mean more or better use of ToM. The Pearson correlation test suggested that the accuracy is not affected by the degree of IBS and we also saw that the mean IBS does not significantly differ between correct and incorrect trials. Furthermore, we saw no significant effect of IBS on accuracy by comparing a model that included IBS as predictor for accuracy to a model without IBS as a predictor. Bases on the combination of these findings we assume that we can not predict the performance on a coordinated ToM task based on only the degree of IBS. This would also suggest that the degree of IBS is not directly related to coordination that requires the use of ToM.

4.2 Limitations

There were a few limitations to the design of this study, of which the most prominent was the difference in difficulty between the two stimulus types. We observed that the accuracy was a lot higher in conditions where color stimuli were used, compared to conditions that used shape stimuli. We did control for this in our statistical models by adding stimulus type as a fixed effect, but this is not a perfect way to handle this. It would be preferred to have a different way of preventing the conventions learned in the first block to carry over into the second block, because then the effect of WM load could be isolated better.

Another limitation were sessions where there was one or more EEG channels that contained pure noise. We excluded these channels and used interpolation to recreate them, however there was still data lost in this process.

4.3 Future research

If WM and ToM indeed use shared brain resources, this would imply that by improving WM you also improve your ability to use ToM. This would be really useful since we already know that we can improve WM through training. Consequently this would mean that we can also train our ability to use ToM which is useful in a lot of situations like coordination in the work place, teaching, and general social skills.

This would be an interesting topic to further explore with an experiment. A study on this could focus on training subjects' WM and seeing if this also improves their ability to use ToM. The WM performance and ability to use ToM of the subjects should be indexed at the start to have a baseline after which the subjects would be split up into two groups. One group would train their WM while the other group would not. After a certain period of time both WM performance and ability to use ToM is measured again and the two groups can be compared to each other. If ToM improved with a linear relationship to WM this would support our findings that WM and ToM use shared brain resources.

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A ToM Related Questionnaire

Autism Spectrum Quotient

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Choose one response that best describes how strongly each item applies to you.

	Definitely Agree	Slightly Agree	Slightly Disagree	Definitely Disagree
1. I prefer to do things with others rather than on my own.				
2. I prefer to do things the same way over and over again.				
3. If I try to imagine something, I find it very easy to create a picture in my mind.				
4. I frequently get so strongly absorbed in one thing that I lose sight of other things.				
5. I often notice small sounds when others do not.				
6. I usually notice car number plates or similar strings of information.				
7. Other people frequently tell me that what I've said is impolite, even though I think it is polite.				
8. When I'm reading a story, I can easily imagine what the characters might look like.				
9. I am fascinated by dates.				
10. In a social group, I can easily keep track of several different people's conversations.				
11. I find social situations easy.				
12. I tend to notice details that others do not.				
13. I would rather go to a library than to a party.				
14. I find making up stories easy.				
15. I find myself drawn more strongly to people than to things.				
16. I tend to have very strong interests, which I get upset about if I can't pursue.				
17. I enjoy social chitchat.				
18. When I talk, it isn't always easy for others to get a word in edgewise.				
19. I am fascinated by numbers.				
20. When I'm reading a story, I find it difficult to work out the characters' intentions.				
21. I don't particularly enjoy reading fiction.				
22. I find it hard to make new friends.				
23. I notice patterns in things all the time.				
24. I would rather go to the theater than to a museum.				
25. It does not upset me if my daily routine is disturbed.				

Score my Answers

	Definitely Agree	Slightly Agree	Slightly Disagree	Definitely Disagree
26. I frequently find that I don't know how to keep a conversation going.				
27. I find it easy to "read between the lines" when someone is talking to me.				
28. I usually concentrate more on the whole picture, rather than on the small details.				
29. I am not very good at remembering phone numbers.				
30. I don't usually notice small changes in a situation or a person's appearance.				
31. I know how to tell if someone listening to me is getting bored.				
32. I find it easy to do more than one thing at once.				
33. When I talk on the phone, I'm not sure when it's my turn to speak.				
34. I enjoy doing things spontaneously.				
35. I am often the last to understand the point of a joke.				
36. I find it easy to work out what someone is thinking or feeling just by looking at their face.				
37. If there is an interruption, I can switch back to what I was doing very quickly.				
38. I am good at social chitchat.				
39. People often tell me that I keep going on and on about the same thing.				
40. When I was young, I used to enjoy playing games involving pretending with other children.				
41. I like to collect information about categories of things (e.g., types of cars, birds, trains, plants).				
42. I find it difficult to imagine what it would be like to be someone else.				
43. I like to carefully plan any activities I participate in.				
44. I enjoy social occasions.				
45. I find it difficult to work out people's intentions.				
46. New situations make me anxious.				
47. I enjoy meeting new people.				
48. I am a good diplomat.				
49. I am not very good at remembering people's date of birth.				
50. I find it very easy to play games with children that involve pretending.				

Score my Answers

Sources

1. M Woodbury-Smith. Screening Adults for Asperger Syndrome using the AQ: a Preliminary Study of its Diagnostic Validity in Clinical Practice. 35(3): J Autism Dev Disord 331-335. 2005.

2. Simon Baron-Cohen, et al. The Autism-Spectrum Quotient (AQ): Evidence from Asperger Syndrome/High-Functioning Autism, Males and Females, Scientists and Mathematicians. 31: J Autism Dev Disord 5-17. 2001.

B Instructions of the experiment

Instructions shown to the participant prior to the actual experiment.

Welcome!

In this experiment you will perform 2 tasks at the same time.

One task involves seeing and selecting images, and the other task involves making decisions about number.

Either one of the following blocks was shown based on the WM load condition:

Low WM load condition

This experiment has 2 blocks.

In the upcoming block, you will see a sequence of numbers, appearing one after another in the center of the screen. Each time a number appears, you will be asked to decide whether it is ‘odd’ or ‘even’.

Each time a number appears, use your right hand to press ‘1’ if the number is ‘odd’, or ‘2’ if the number is ‘even’.

You will have limited time to respond, so try to be quick!

Let’s practice.

3 number trial practices

Number practice has ended.

Your final payment will be based partly on your accuracy in this number task. The more accurate you are, the more money you will receive at the end of the experiment.

High WM load condition

This experiment has 2 blocks.

In the upcoming block, you will see a sequence of numbers, appearing one after another in the center of the screen. Each time a number appears, you will be asked to decide whether you saw the same number 2 trials ago.

To begin with, let’s practice deciding if you saw the same number 1 trial ago.

Each time a number appears, perss ‘1’ if the number is the same as 1 trial ago, or ‘2’ if the number is different.

You will have limited time to respond, so try to be quick!

3 number trial practices

Practice has ended.

Next, let’s practice deciding if you saw the same number 2 trials ago.

Each time a number appears, press ‘1’ if the number is the same as 2 trials ago, or ‘2’ if the number is different.

You will have limited time to respond, so try to be quick!

3 number trial practices

Number practice has ended.

Your final payment will be based partly on your accuracy in this number task. The more accurate you are, the more money you will receive at the end of the experiment.

In addition to the number task, you will also perform an image task with the other player.

You and the other player will see 4 abstract images on the screen. In the upcoming block, the images will be made of different colors. Your aim is to try selecting the same image as each other, but you are not allowed to talk or communicate in any way.

You will be able to make a first choice (first-best guess) and a second choice (second-best guess).

After choosing an image, your first choice and the other player’s first choice will both be shown on the screen, so you can become familiar with each other’s choices. Then you both will start another trial with a new set of images and repeat the same process.

3 image trial practices

Image practice has ended.

You and the other player will go through many trials to become familiar with each other’s choices.

You may not speak to each other, so pay careful attention to what the other player selects! And remember that the other player is also paying attention to what you select!

The more times you match with your partner’s FIRST or SECOND choice, the more money you will receive as final payment. Both your FIRST and SECOND choices are important!
Note: Choosing an image based on position, e.g. choosing the first left-most image, is not a viable strategy because IMAGES ARE NOT NECESSARILY DISPLAYED IN THE SAME POSITIOINS FOR BOTH PLAYERS! Try to make your decisions based on features of the images, not their position!

3 number trial practices

Practice has ended.

Next, let’s practice deciding if you saw the same number 2 trials ago.

Each time a number appears, press ‘1’ if the number is the same as 2 trials ago, or ‘2’ if the number is different.

You will have limited time to respond, so try to be quick!

3 number trial practices

Number practice has ended.

Your final payment will be based partly on your accuracy in this number task. The more accurate you are, the more money you will receive at the end of the experiment.

In addition to the number task, you will also perform an image task with the other player.

You and the other player will see 4 abstract images on the screen. In the upcoming block, the images will be made of different colors. Your aim is to try selecting the same image as each other, but you are not allowed to talk or communicate in any way.

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After choosing an image, your first choice and the other player’s first choice will both be shown on the screen, so you can become familiar with each other’s choices. Then you both will start another trial with a new set of images and repeat the same process.

3 image trial practices

Image practice has ended.

You and the other player will go through many trials to become familiar with each other’s choices.

You may not speak to each other, so pay careful attention to what the other player selects! And remember that the other player is also paying attention to what you select!

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