Development of Theory of Mind Stimuli in Magnetoencephalography for Nursing Evaluation

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Abstract

We introduce the development of animation stimuli for theory of mind (ToM) in magnetoencepalography (MEG). We will discuss apparatus for presenting animation stimuli and a technical problem like an eye movement signal generated from following triangles in the animations, and its rejection using independent component analysis (ICA). With the ToM animations and the apparatus, we conducted MEG measurements for 8 normal controls and 6 schizophrenic patients. We present a preliminary assessment result for the developed animation stimuli as a tool for ToM test, which has been obtained by scoring in the following-up interview after the MEG measurement.

Keywords: *Theory of mind (ToM), Magnetoencephalography (MEG), Magnetooculogram (MOG).*

1. Introduction

Theory of Mind (ToM) is an ability to understand or to predict other's behavior in specific situations. Such ability come from reading others thought, belief, desire, and intention based on social activities like words, emotion and behavior. A person who has the ToM ability can understand that behaviors are determined by one's own knowledge or confidence based on his/her experiences. This ability is developed when they are around four-to-five years old. Meanwhile, the schizophrenia has difficulties to understand other's intention and what effects could be exerted to the others hence, they tend to feel difficulty in social relationship. Baron-Cohen, et al. reported that such a problem is caused by defects in the ToM development [1]. The difference between ToM process and Non-ToM process in brain function areas is studied with positron emission tomography (PET), functional magnetic resonance imaging (fMRI); the dominant corresponding region for ToM is well-known to be located in the medial prefrontal cortex (mPFC) and posterior superior temporal sulcus (pSTS) [3-8]. The responses on the sites are clear for normal subjects when they are doing task related to ToM while the schizophrenia and the autism do not show significant activity on the sites [7]. This result supports the assertion of Baron-Cohen [8]. In the first stage, most of experiments used simple cartoons or story-telling false-belief tests as the stimulus:

① The Sally-Ann test [1] and Smarties test

→ First-order false belief ‘ she thinks x’

② The Ice-Cream story and Birthday Puppy Test [2]

→ Second-order false belief ‘ she thinks that he thinks x’

→ Subjects who failed control questions were excluded from participating in the study

However, such stimuli are several problems like a spurious response to instructor's facial expression and gestures. Moreover, such stimuli or tools are hard to apply to the schizophrenia and the autism because of their weak attention and patience. Especially, in magnetoencephalography (MEG), a subject should be located alone in a magnetically shielded room and we need to make a proper stimulus which can easily attract subject's attention. For the purpose, we adopted animation stimulus containing interacting triangles which represent individual's intention and emotion. This animation is called Heider-Simmel animation and we do not need to ask special instructions to subjects. Such aspects are advantageous so that several research of ToM with Heider-Simmel animation has been reported [4-8].

In this study, we introduce the development of ToM animation stimuli for MEG experiments. We will discuss apparatus for presenting animation stimuli and technical problems and solutions for them. Moreover, we will present a preliminary assessment result for the animations as a tool for ToM test.

2. Magnetoencephalography

Most of studies on the difference in the brain activity between normal controls and the schizophrenia have been conducted with PET or fMRI. However, such modalities have poor time resolution while they have quite a good spatial resolution. Therefore, they can be used for localizing general activity but they are not enough to study the rapid interaction in the brain connectivity. Meanwhile, MEG has high temporal resolution of ms, which is proper to analyze high-order cognitive functions like ToM. Only limitation of MEG is the fact that MEG is not sensitive for a deep source. While MEG has as good spatial resolution as fMRI for current dipole sources on the neocortex, it is not as good for deep activities such as excitation in amygdala. Generally, MEG is believed to be inappropriate for high-order cognitive research since high-order cognitive processes are involved with such deep sources. However, as mentioned in the introduction, the dominant ToM sources are known to be around mPFC and pSTS and those sources are located on relatively shallow position. Hence, ToM is a good subject to be studied with MEG. Figure 1 shows MEG system. Since an MEG system measures very weak magnetic fields from neuronal currents, which strength is about hundreds femtoTesla, we need to shield external magnetic fields including the earth magnetic field. Therefore, an MEG sensor helmet should be placed in a magnetically shielded room (MSR) shown in Figure 1. Inside of MSR, all the electromagnetic interference should be suppressed. Thus, we cannot use LCD monitor for the purpose of displaying the animation stimuli. So we need to develop non-magnetic displaying devices. In this study, we have used a compact portable beam projector. The small projector was shielded with mu metal and located far from the sensor helmet. We placed a see-through screen in front of a subject and the projector makes an image on the screen (Figure 2). The beam projector was battery-operated to prevent intervention of the power line noise. Besides, in the MSR, we equipped fiber optic buttons. Switching signal of the button is transmitted with light so that the button would not generate any electrical noise. These buttons are used to decide when to run and when to stop the animation. By asking subjects to decide the timing, we can keep their attention.

Figure 1. Magnetoencephalograph (MEG) system. A helmet-shape SQUID sensor array is located in a magnetically shielded room.

Figure 2. Displaying apparatus for presenting animation stimuli. The apparatus consists of a see-through screen in front of a subject and a shielded compact beam projector.

3. Method and Measurements

Eight normal subjects and six schizophrenic patients participated in this study (all right-handed, 4 males of average age 29.5 and 4 females of average age 24.8 in the control, 3 males of average age 35.7 and 3 females of average age 33.3 in the schizophrenia). The ToM stimuli were provided in the form of short animations during MEG measurements. Experimental stimuli developed by F. Happe [8] which was based on Heider-Simmel animation was used. The animations consist of one large and another small triangles moving around the screen, 30s time long, and they were categorized into three groups depending on movement aspects; random interactions (RI), goal-directed interactions (GDI) and ToM interactions (ToMI), respectively (Figure 3):

① Random with 2 animations; the triangles did not interact with each other (purposeless moving).

② Goal-directed action with 4 animations (following, fighting, chasing, dancing); the smaller triangle following the bigger one, the triangles fighting with each other, a chasing one another, the characters dancing together → no implication that one character was reading the other's mind

③ ToM with 4 animations (seduce, persuade, mocking, coaxing, surprising); one character tried to seduce and persuade the other to let it free, the small triangle mocking the big one behind its back, the big triangle coaxing the little one out of enclosure, the little one hiding behind a door and surprising the big triangle → one character reacting to the other's mental states

The presenting sequence for a set was randomly-mixed 4 RI, 2 GDI, 2 ToMI. After the MEG measurement, subjects were asked to describe the contents of the animations and the degree of understanding (DoU) was scored.

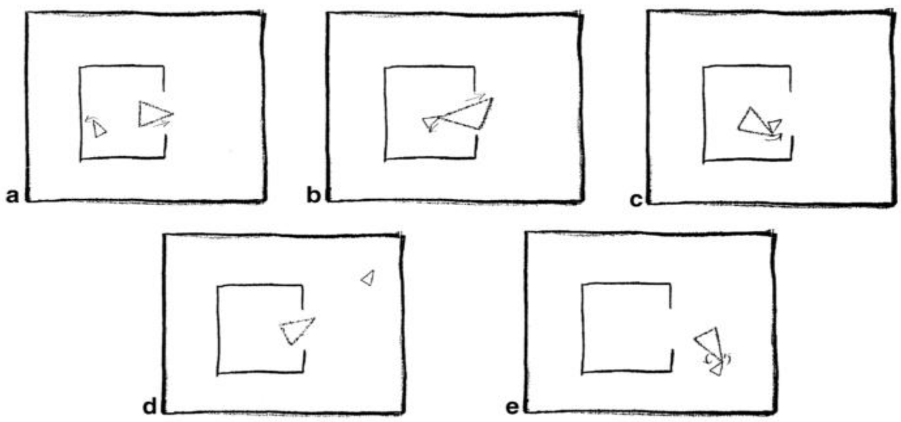

Figure 3. Animation with motion of two personalized triangles (This figure is on the courtesy of Castelli et al. (2002) of Ref. [9])

MEG data were recorded with a whole-head helmet system (KRISS MEG System, KRISS, Daejeon, KOREA) within a magnetically shielded room. The data were sampled at 500 Hz after analog filtering with a 60-Hz notch and 100-Hz low pass filter. The system has 152 axial first-order double relaxation oscillation SQUID gradiometers.

The animation is projected to a screen in front of the MEG system and the subjects are requested to press a button at the beginning and the end of each sequence for attention to the animations. A set consists of 8 animations and we showed two sets for each subject one by one. After showing each set, we did an interview for the sequences to score the level of understanding.

4. Signal Processing: Rejection of Magnetooculogram

The animation stimuli do not need any action of subjects, which is feasible to invoke the attention. Moreover, the movements of the simplified figures prevent a spurious excitation. However, the eye movements following the moving figures are unavoidable, which generate strong magnetooculogram (MOG) fields [11] on the sensing channel in the frontal (Figure 4). We developed an automatic MOG rejection algorithm based on a spatially-profiled independent component analysis (ICA) and it successfully eliminates the MOG signals (Figure 5).

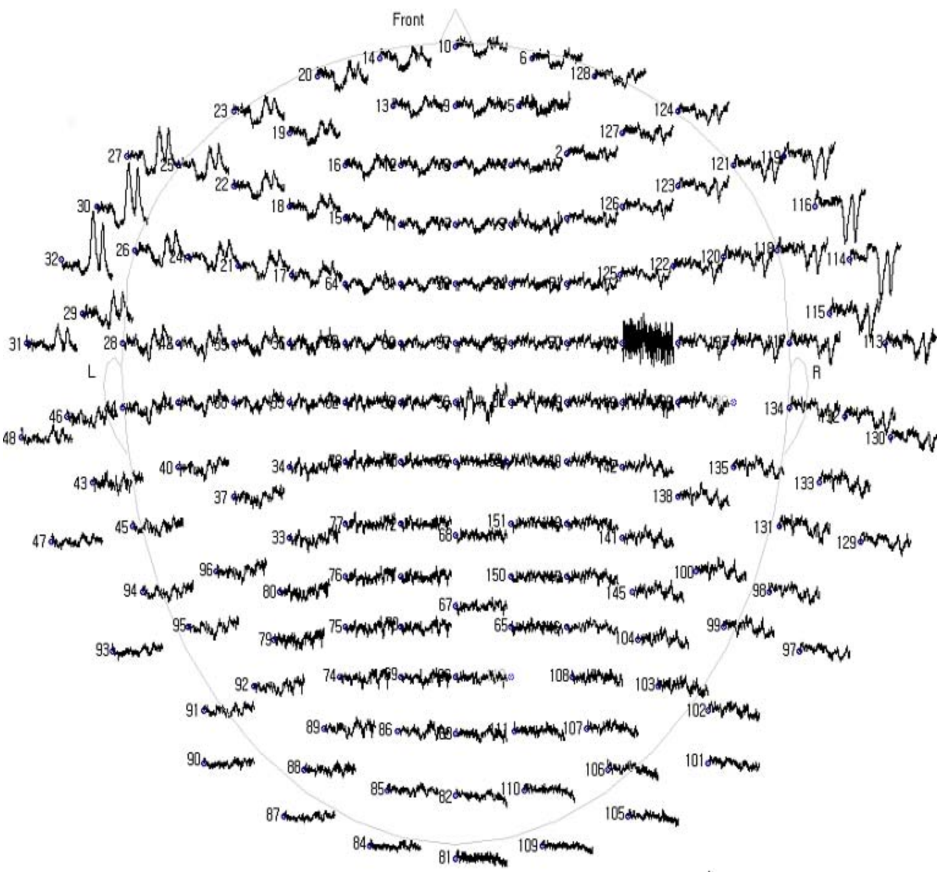

Figure 4. Real-time MEG measurement. On the channel located near eyes, we can see strong peaks come from eye-ball movements. Note that the signal phase is inversed each other in the left and the right signal channels (channel left: 27, 30, 32; channel right: 114, 116, 119)

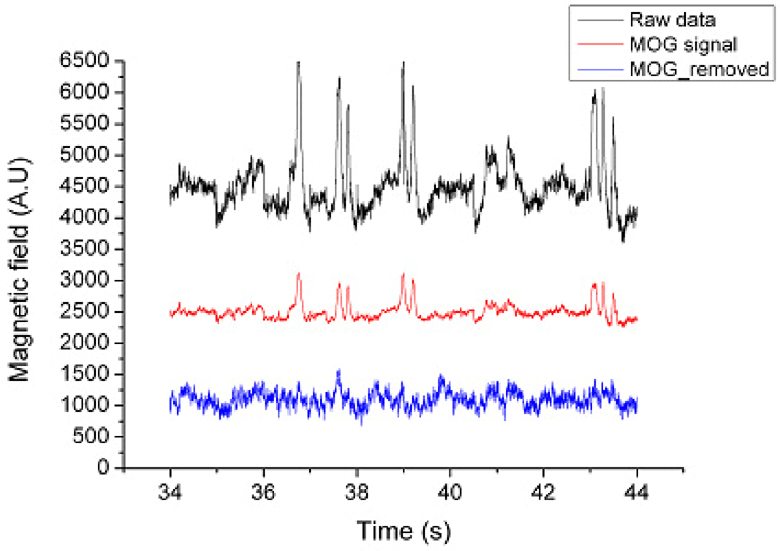

Figure 5. Eye movement signal (MOG) rejection. Independent component analysis has been utilized to separate the MOG signal from the raw signal. The automatic MOG rejection is quite successful

5. Results

The Score of the subjective understandings for participants after showing animation is as follows. Table 1 shows the mean and standard deviation of the interview score. In scoring, if the statement of an interviewee is perfectly matched with the task, interviewer gives 2 points; if the statement is partly explain the task, 1 point; if the statement is not relevant to the animation, then 0 point. In the scoring, we followed the scoring criteria of Abell et al [10].

The score is summarized in the bar graph in Figure 6. Schizophrenia group had a lower score than normal controls on all tasks. Patients group showed a lower score of ToM compared to normal controls. This result is consistent with the findings of previous study [10]. No significant difference was observed between the male group and the female group on RI, GDI, and ToMI.

Table 1. Score of the RI, GDI, ToMI task in each groups.

Group	Random Mean(SD)	Goal-Directed Mean(SD)	Theory of Mind Mean(SD)
Normal male	1.67 (0.64)	1.92 (0.29)	1.67 (0.49)
Normal female	1.44 (0.84)	1.75 (0.58)	1.63 (0.62)
Schizophrenia male	0.90 (0.72)	1.00 (0.94)	0.70 (0.57)
Schizophrenia female	1.18 (0.85)	1.33 (0.89)	0.58 (0.67)
Normal all	1.54 (0.76)	1.82 (0.48)	1.64 (0.56)
Schizophrenia all	1.05 (0.79)	1.18 (0.91)	0.82 (0.66)

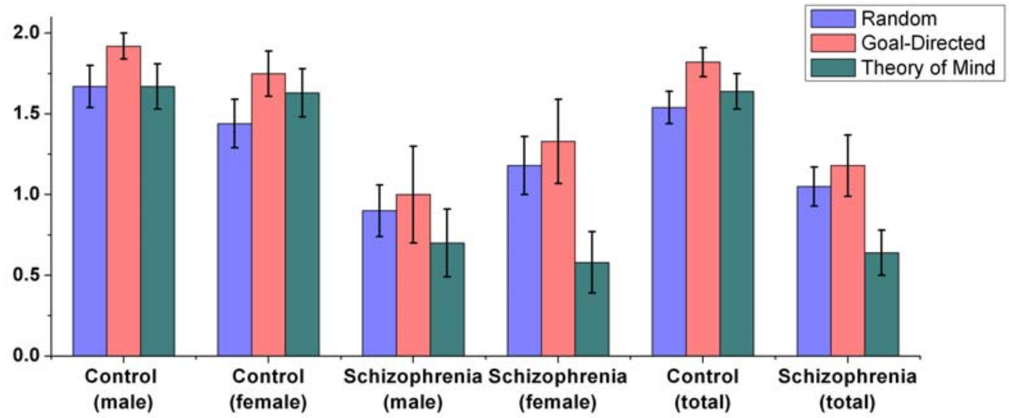

Figure 6. Score of each subject group category. Note the significant difference between the normal controls and the schizophrenia. There was no significant difference depending on sex

6. Conclusion

We developed animation stimuli for ToM measurements with MEG. We have tested our sequence paradigm with a newly developed non-magnetic displaying apparatus. The paradigm based on animation has many advantage but it generates eye movement noise. To eliminate the MOG signal, we introduced automated spatially-profiled ICA and the result was satisfactory. The stimuli used in the MEG measurement shows clear difference between the normal and the schizophrenia. As a future work, once the following MEG signal analysis finds good parameter, we can get new neurophysiologic criteria to assess the severity of mal-function in ToM process. The new criteria can be objective assessment criteria to measure improvement of social function with rehabilitation programs for the schizophrenia.

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