How does a doll play affect socio-emotional development in children?: Evidence from behavioral and neuroimaging measures

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Abstract

Mentalization is an important ability to acquire for children, as it allows humans to understand the mental state of others or oneself, that underlies overt behavior (Fonagy & Target, 1996). In the current study we examined the relationship between development of mentalization ability in children and their experience of playing with a doll by observing child-mother interaction and by using functional near-infrared spectroscopy (fNIRS). 44 dyads of children aged 2 to 3 and their mothers were divided into two groups (high and low) depending on the frequency of doll-play experience. We examined mother-speech interaction during the doll play. We also used fNIRS system to measure cerebral hemodynamic activation in the frontal and temporal regions during the observation of video clips showing hindering and helping behaviors. The results showed that a mother's proxy talk was related to a child's doll directed speech in the high group, but not in the low group. fNRIS data showed that cerebral activation in the helping condition was more increased in the low group than the high group. This suggests that doll-play experience facilitates the development of mentalization, which enables children to be aware of and understand other's psychological states.

Keywords: doll play; social understanding; mentalizing, young children; fNIRS.

This study investigated the relationship between children's experience in playing with dolls and the development of mentalization by using behavioral and neuroimaging measures. Mentalization refers to an ability to speculate and to understand other's psychological states (e.g., needs, desires, feelings, beliefs, goals, and reasons) based on their behavior (Fonagy, Gergely, & Target, 2007). Development of mentalization is important for children, as they need to interact with others by assuming other's mental sates in their socialization process. Fonagy and Target (1996) have suggested that play provides an intermediate area for the acquisition of symbolic thinking which is crucial for mentalization. Given this, it is important to see the relationship between play and the development of mentalization.

Children around age 1 begin to play by using an object as if it were something else or by pretending as if he or she was doing an actual action without the visible object. This kind of play is called "pretend play'. Pretend play is defined as a play expressing internal images by using actions, words, or objects, such as pretending to drink water by moving an empty cup to her mouth or feeding a doll by moving an empty toy fork to a doll's mouth (Lillard, Lerner, Hopkins, Dore, Smith, & Palmquist, 2013). Research has investigated pretend play because it indicates the emergence of mental representation in children in the sense that they enact an event or represent an invisible object by using their own body or different objects during play.
Pretend play normally peaks around preschool years when children start interacting with other children and gain access to more toys and resources for play (Lindsey & Colwell, 2013). Pretend play during preschool age is particularly important as it is related to the development of language (e.g., Orr & Geva, 2015), executive function (e.g., Carlson, White, & Davis-Unger, 2014), and social understanding including theory of mind (e.g., Lillard & Kavanaugh, 2014). Theory of mind refers to the ability to attribute mental states to others in order to understand and predict social behavior. The difference between mentalization and theory of mind is that mentalization mainly concerns the reflection of affective mental states, whereas, theory of mind focuses on epistemic states such as beliefs, intentions and persuasions (Wyle, 2014).
However few studies have shown the relationship between children's experience in pretend play and the development of mentalization. The current study addressed this issue.

Sachet and Mottweiler (2013) emphasized the distinction between two types of pretend play; Role-play and Object Substitution. *Role play* refers to pretend play that involves the mental representation of social or interpersonal content (e.g., pretending that a doll likes to eat sweets), whereas *object substitution* refers to pretend play that involves the mental representation of nonsocial content (e.g., pretending that a block is a chocolate). Both types of pretend play can provide opportunities for children to practice social skills or events happenings in the real world. Role-play has a special significance in the development of social understanding, because it provides opportunities for simulating social interaction (Harris, 2000). In fact, this was demonstrated by Wolf, Rygh, and Altshuler (1984). They visited children's houses from ages 1 to 7 and recorded their play with replica toys. They found that by the age of four, children can ascribe complicated psychological states including perceptions, sensations, emotions, and thinking to figures with which they are playing (Wolf et al., 1984). However there are three limitations in the previous studies on pretend play.

First, little research has been conducted to address how doll play affects social development such as mentalization, sympathy or prosocial behavior. Most studies have focused on object substitution and how it is related to social or cognitive development. Given that doll play provides opportunities for simulating social interaction (Harris, 2000), playing with a doll may foster children's social understanding. Brownell, Svetlova, Anderson, Nichols, and Drummond (2013) observed an interaction between toddlers and caregivers while reading a picture book in relation to toddlers' prosocial behavior. They found that children who helped and shared more tended to have parents who more often asked them to label and explain the emotions depicted in the books. This result suggests that caregiver's inputs that direct children's attention to inner thoughts or feelings of themselves or others assist the development of children's social understanding including mentalization.

Second, it is not clear how children's ability to ascribe the psychological states to dolls develops up until 4 years old. Lillard (2017) suggested that parent's input in pretend play is a crucial factor to develop children's social understanding because children need to learn how to pretend by properly interpreting social signals that parents send (e.g., strong eye contact or smile) as a cue of pretend play. Thus, it is worth investigating both children's and parent's behaviors during doll play to see how it affects the development of social understanding by the age of 4 years old.

Third, as Lillard (1993) pointed out, pretend play has been mostly analyzed by behavioral measures. There is no neuroimaging work on pretend play in children, although there are a few that have been done with adults (German et al., 2004; Whitehead et al., 2009). To see whether an experience in doll play affects the development of mentalization, the present study used functional near-infrared spectroscopy (fNIRS). Compared with other neuroimaging techniques, fNIRS imposes less physical constraints on the participant and it is relatively unaffected by motion artifact. Thus it can be applied in a natural setting even in young children (Nagamitsu, Yamashita, Tanaka, & Matsuishi, 2012). Previous studies have shown that medial prefrontal cortex (mPFC) and temporoparietal junction (TPJ) are involved in the mentalization process (Frith & Frith, 2006; Minagawa Xu, & Morimoto, 2018). Particularly mPFC is responsive when making social judgments about dissimilar others (Mitchell et al., 2005), whereas TPJ is activated more in response to theory of mind tasks (Mahy, Moses, & Pfeifer, 2014). Thus, if a doll-play experience facilitates the development of mentalization ability in children, these brain regions would be activated more in children having more experience in doll play than those who have less experience.

To address these three limitations, the current study aimed to reveal the relationship between doll-play experience and development of mentalization in children aged 2 to 3 by observing mother-child interaction and measuring fNIRS. We predicated that fNIRS data would show that brain areas involving the mentalizing process would be more activated in children having more doll-play than children having less experience when they see someone's helping/hindering behavior. We also predicted that mother-child interaction would be qualitatively different depending on children's doll-play experience.

Methods

Participants 44 female children aged 2 to 3 and their mothers participated in this study. They were divided into two groups in terms of frequency of doll play; high and low group. The playtime with a doll was taken via a questionnaire for mothers before the experiment. Each group included 22 children. Children in the High group play with a doll more than one hour per week, and children in the low group play with a doll fewer than 20 minutes per week. The mean age in months and the standard deviation for each group were as follows; Low group, M = 35.4, SD = 2.5, and High group M = 36.7, SD = 3.3. There was no significant difference in the average age between the two groups. All the participants were native monolingual Japanese speakers from middle-class families, and the children attended nursery schools in Tokyo, Japan.

Material and Apparatus The test consisted of two sessions; a doll play session and a fNIRS session. In the doll play session, the child-mother dyad participated in a 7-minute doll play session. We encouraged the child-mother dyad to play with a set of toys including a doll and replica of house items, as shown in the left panel in Figure 1. Experimenters recorded the child-mother interactions but did not participate in their play.

For fNIRS session, we created audiovisual video clips. Each video clip lasted 17sec (30 fps), presenting two girls making an event as shown in Figure 2. In total, we created nine clips (stories). After presenting a still picture for 0.5 second, each clip starts with the introduction phase (8.5sec) where one girl (girl A) is in need and the other girl (girl B) notices the trouble (e.g., girl A is looking for a pencil, and girl B notices it). Then each story ends with the ending phase (8sec), which has two types of endings; hindering vs. helping ending. In the hindering condition, girl B obstructs girl A's need (e.g., throwing the pencil away), whereas in the helping condition, girl B assists girl A's need (e.g., passing the pencil to girl A).

Figure 1. Toys used in doll play session (left panel) and a screenshot of data coding with ELAN (right panel).

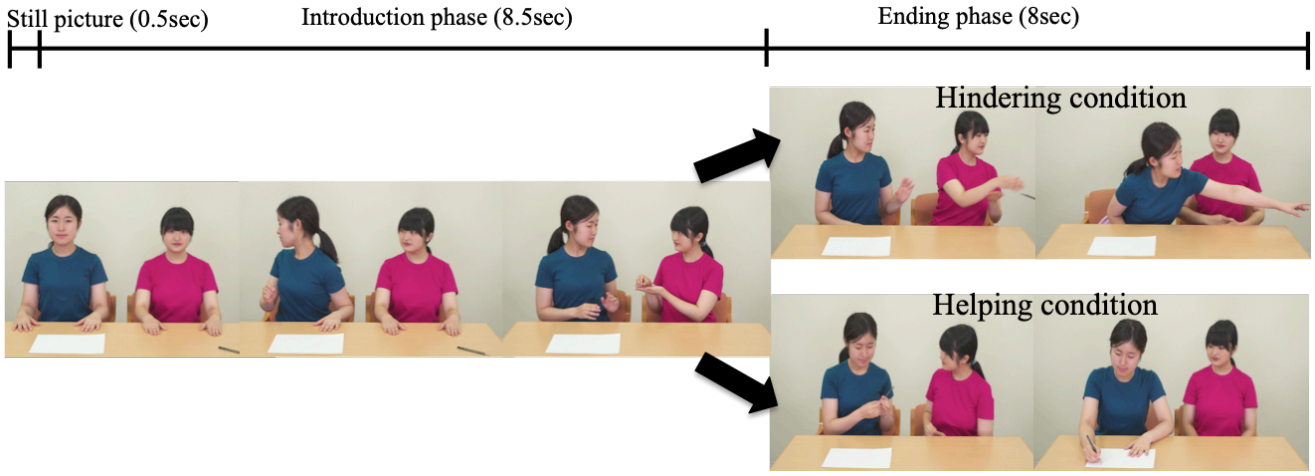

Figure 2. An example of video audio stimulus and the time line for fNIRS experiment. Each clip has two different endings; Hindering (top) and helping ending (bottom) in the Ending phase.

Procedure

The experiments were conducted in a test room with a sound-attenuated cabin for fNIRS in Keio University in Tokyo, Japan. First, each child-mother pair was instructed to play with a doll and some house items, shown in Figure 1, for seven minutes. They were encouraged to play in the same way as they do in their home. After the doll play session, they had a short break and moved to a booth with the fNIRS device. In the booth, mothers were instructed to hold their children on their laps and not interact with them during the fNIRS data collection. Children were instructed to watch the video clips on the monitor in front of them. The whole session was recorded using the mini-DV camcorder on a tripod. We counterbalanced the number of ending types that children were presented with, the locations of girl A and B, and the role of girls (e.g., one child watched the girl A helping in the pencil story, but other child watched the girl B helping in same story).

Analysis

Doll play data All narratives were verbatim transcribed. From the transcriptions, the mean number of utterances was then calculated. In this study an utterance was defined as a breath group. A breath group refers to a stretch of speech between two interword pauses, lasting 200ms or longer. We excluded an utterance from this study when it consisted of only fillers or meaningless exclamations such as "ah" or "um".

We counted the number of the following three speech types (*Desires, Emotion labels,* and *other internal state talk*) by using coding software ELAN (Lausberg & Sloetjes, 2009) (right panel in Figure 1). These categories were borrowed from a study by Brownell et al. (2013). *Desires* are references to wanting, or needing something concrete such as "he wants to eat an apple" or "she needs to go to bed". *Emotion labels* are defined as an utterance naming emotional feelings or behaviors without expansion or elaboration such as "the doll is happy" or "she likes vegetables". Other internal state talk is references to other internal states that are not affect- or mental state-related (e.g., physiological states) such as "she is thirsty" or "the doll is tired".

To see the psychological distance between participants and the doll, we also counted the number of instances of *proxy talk* and of *doll directed speech*. Proxy talk refers to an utterance when the speaker says something from doll's perspective, just like a ventriloquist, as if she or he is the doll (e.g., "oh I am so hungry, can you make a meal for me?"). In addition to the content of the utterance, if the pitch of the speaker's voice heightens higher than their usual pitch and/or he or she produced the utterance while operating the doll, it was counted as proxy talk. Doll directed speech refers to an utterance that directly addresses to the doll (e.g., "I will cook something for you").

fNIRS data We measured changes in concentrations of oxy-hemoglobin (oxy-Hb) and deoxy-hemoglobin (deoxy-Hb) in the frontal and temporal regions during the observation of video clips, using the NIRS system (ETG-7000, Hitachi). The NIRS system measures temporal changes in concentrations of oxy-Hb and deoxy-Hb in the cerebral cortex resulting from an increase in local cerebral blood flow by emitting and detecting two wavelengths of near-infrared light (780 nm and 830 nm). We used a 2 x 11 optode array, containing 27 measurement channels. The center optode in low row was placed on Fpz in the international 10-20 system to cover the frontal and temporal regions (Figure 5). The distance between each emitter and the corresponding detector was set at 2.5 cm.

Data was preprocessed using a platform for optical topography analysis tools (POTATo) developed by Research and Development Group, Hitachi, Ltd, within MATLAB2012 (Mathworks, Natwick, MA, USA). Pulse-related signal changes for head motion and overall trends were eliminated by high-pass (0.02 HZ) and low-pass (1 Hz) filtering. We defined 3.5 seconds before the onset of the ending phase as a baseline period and compared the relative change in oxy-Hb during a time analysis window (between 5 s and 8 s after the onset of the ending phrase) with the baseline period using a t-test. It is controversial which chromophore, namely oxy-Hb or deoxy-Hb best represents

BOLD (blood oxygen level dependent) signal. However, oxy-Hb has been dominantly used in previous fNIRS studies (Lloyd-Fox et al., 2010) and it has been pointed out that signal-to-noise ratio is higher for oxy-Hb rather than deoxy-Hb (Strangman et al. 2002). Thus, we decided to analyse only oxy-HB in this study.

Reliability

The first author coded the entire data set. To ensure the reliability of the gesture coding, about 50% of the data was re-analysed by a trained and independent native Japanese-speaking student. Ten children and mothers from each group (40 participants in total) were randomly selected and re-coded by the second coder. Point-to-point percentage agreement was calculated. The two coders agreed on the number of utterances 98% of the time for children, 97% of the time for mothers in the low group, and 98% of the time for children, 98% of the time for mothers in the high group. We calculated the percentage agreement for each speech category by collapsing groups. The two coders agreed on the number of doll directed speech 90% of the time in the low group and 93 % of the time in the high group, and on the number of proxy talk 93% of the time in the low group and 88% of the time in the high group. The Cohen's kappa statistic was used to assess inter-rater reliability for coding with more than two categories. Agreements between the two independent coders were overall high; for the low group, for desire speech kappa=.91; for emotion label kappa=.89; for other internal state talk kappa=.93, and for the high group, for desire speech kappa=.94; for emotion label kappa=.96; for other internal state talk kappa=.95. Any coding disagreements were resolved through discussion and subsequent consensus.

Results

1.1. Doll play analysis

The number of utterances We first calculated the number of utterances that children and mothers produced for each group. Children produced 46.3 (SD = 19.6) utterances in the low group, and 57.2 (SD= 26.9) in the high group. Mothers produced 121.3 utterances (SD = 26.3) in the low group, and 115.5 (SD = 26.8) in the high group. We conducted independent-sample t-tests and did not find a significant difference between the two groups, $t(42) = 1.53$, $p = 0.13$, for children, and $t(42) = 0.73$, $p = 0.47$, for mothers. This result showed that children and mothers in both groups produced same amount of utterances during the doll play.

Proxy talk and doll directed speech We first counted the number of instances of proxy talk and doll directed speech that were produced by children and mothers during the session. Then we divided them by the total number of utterances for each participant to calculate the proportion. The proportions of proxy talk were 0.00 (0.01) in children in the low group, 0.02 (0.02) in children in the high group, 0.13 (0.11) in mothers in the low group, and 0.37 (0.19) in mothers in the high group. To see whether there was a difference in the proportion of proxy talk between the low and high groups, after arcsine transformation of the proportion data, independent-sample t-tests were conducted for children and mothers. A significant difference was found in children, $t(42) = 3.39$, $p < .01$, $d = 1.02$, and in mothers, $t(42) = 5.00$, $p < 0.01$, $d = 1.51$. This result indicated that mothers and children in the high group produced proxy talk more frequently than those in the low group. The proportions of doll directed speech were 0.06 (0.09) in children in the low group, 0.23 (0.17) in children in the high group, 0.00 (0.00) in mothers in the low group, and 0.00 (0.01) in mothers in the high group. Independent-sample t-tests were conducted, and a significant difference was found only in children, $t(42) = 3.39$, $p < .01$, $d = 1.59$. This result indicated that children in the high group produced doll directed speech more frequently than children in the low group.

Correlation between proxy talk and doll directed speech

To see whether there was a relationship between mother's and children's statements, Pearson's correlation coefficient was calculated between the proportion of proxy talk and of doll directed speech made by mothers and children for each group. The result revealed that in the low group, there are no correlations between them, but in the high group, there is a significant correlation between mother's proxy talk and children's, $r = .69$, $p < .001$ (two-tailed). This indicated that when mothers produce proxy talk, their children produce doll directed speech during their play in the high group.

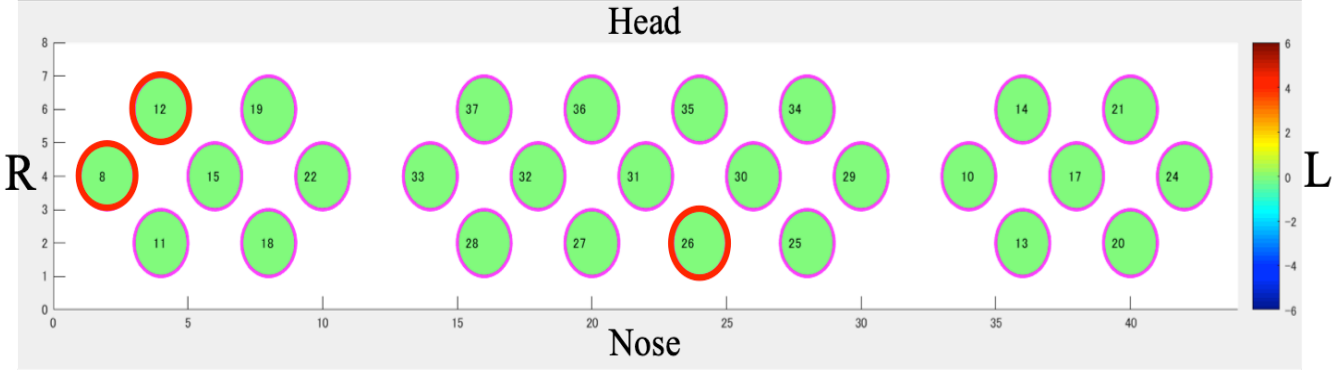

Figure 5. Arrangement of the near-infrared spectroscopy (NIRS) channels. The channels with a red circle indicate the channels showing the significant difference between the low and the high groups.

Proportion of speech type in children and mothers Proportions of each speech type were calculated by dividing the number of each speech type by the total number of utterances for children (Figure 3) and mothers (Figure 4). After arcsine transformation of the proportion data, paired t-tests were conducted for each speech type between two groups in children and mothers. A significant difference was found only in Emotion labels in adults, $t(42) = 2.43$, $p < .05$, $d = 0.73$. This indicates that mothers in the high group produced Emotion labels more frequently than those in low group.

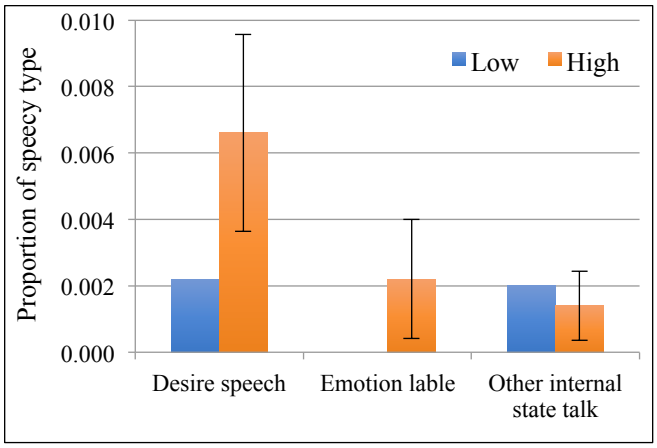

Figure 3. Proportion of each speech type in children

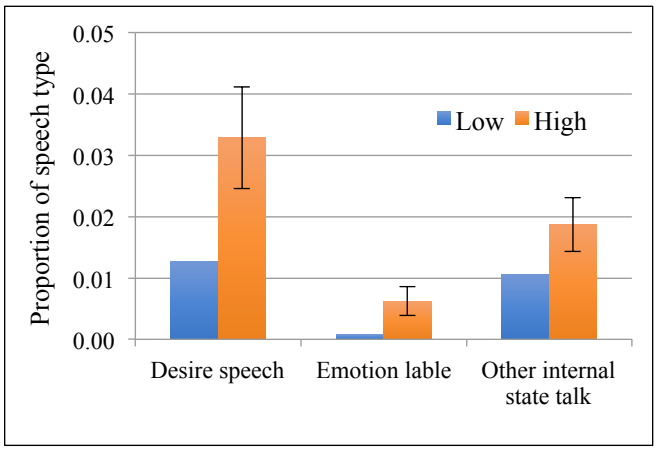

Figure 4. Proportion of each speech type in adults

2. 1. fNIRS analysis

We conducted paired t-tests on the difference in oxy-Hb change during the ending phase between two groups (the high vs. low group) for each channel, and for each condition (hindering and helping condition)

The result showed that there were no significant differences between two groups in the hindering condition, but the oxy-Hb concentration in the helping condition was significantly more increased in the low group than the high group for the measurement channel 8, $t(27) = 3.05$, $p < .01$,

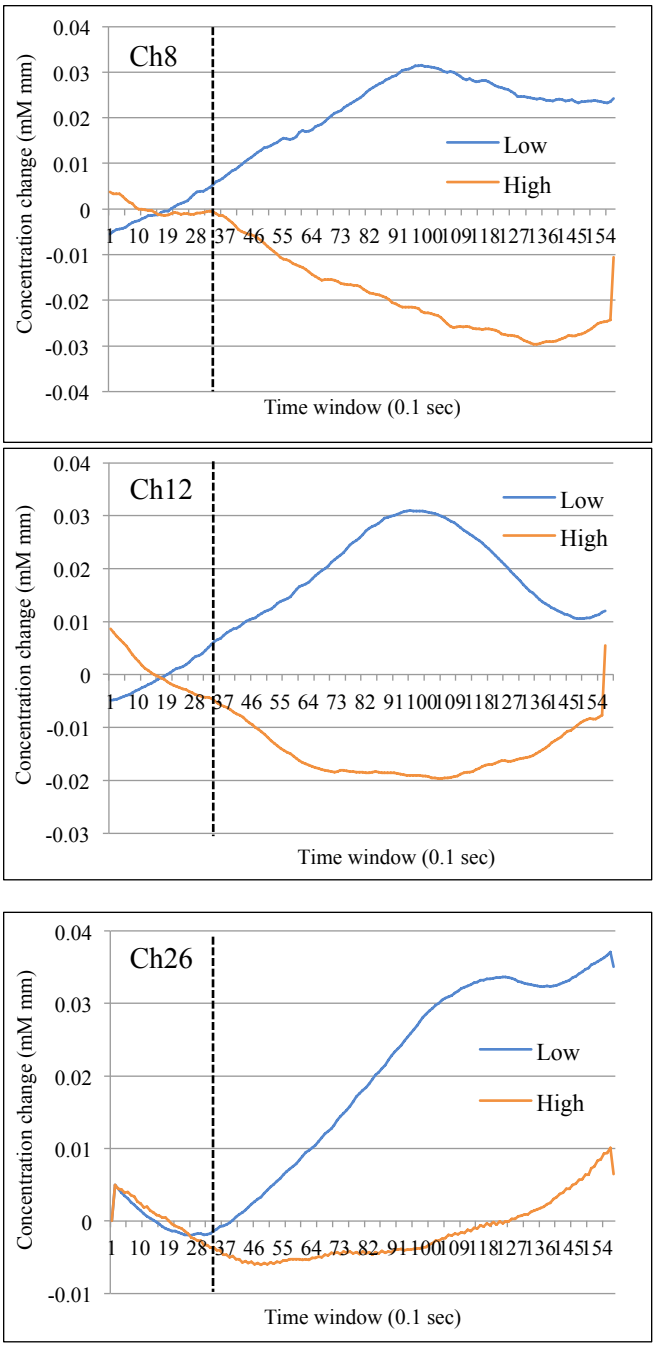

Figure 6. The time course of signal changes in oxy-Hb at TPJ (Ch8 and 12) and mPFC (Ch26) channels during the ending phase. The x-axis represents time units of 0.1 second. The dot line indicates the onset of the ending phase. We analysed the last 3 seconds of the ending phase, which is time windows from 85 to 115 on x-axis.

$d = 1.12$, the channel 12, $t(29)=3.58$, $p < .001$, $d = 1.29$, the channel 26, $t(30)= 3.28$, $p < .01$, $d = 1.16$. The channel 8 and 12 cover TPJ (temporoparietal junction) region, and the channel 26 covers mPFC (medial prefrontal cortex) region.

Taking TPJ's and mPFC's functional roles into account, these results suggested that children in the low group are more sensitive to other's helping behaviors and feelings than those in the high group. We conducted the correlation analysis between behavioral data (child/mother speech) and the three channels showing the significant differences between groups. However, any statically significant correlations between them were not found.

Discussion

The current study examined the relationship between doll-play experience and development of mentalization in children aged 2 to 3 by observing mother-child interaction and measuring brain activation by fNIRS. We found three main results. The first finding is that mother's talk differs depending on children's experience in playing with dolls. Mothers who have children with more experience in doll-play tended to produce more proxy talk and emotion labels during doll-play than mothers in the low doll-play experience group. The second finding is that children who have more experience in doll-play produced doll directed speech more frequently than children who have less experience in doll-play.

These findings indicate that mentioning a doll's internal feelings or talking to children by using the doll's voice direct children's attention to a doll's inner psychological states, which may lead children to the development of mentalization. In turn, children tend to talk to the doll as if the doll is an animate entity by using doll directed speech. This interpretation is consistent with previous research showing that mother's inputs are important to develop children's social understanding (e.g., Brownell et al., 2013; Lillard. 2017; Nakamachi, 2015). For example, Nakamachi (2015) found that mothers' pretend behaviors when toddlers were at 18 months predicted toddlers' understanding of a stranger's pretense 6 months later. Our data added new insight to this line of research. That is, as the result of correlation analysis shows, mother's proxy talk was significantly correlated to children's doll directed speech in the high doll-play experience group. Although it is difficult to determine the cause-effect relationship from our data set, we can speculate that mother's proxy talk makes children aware of a doll's inner feelings. In turn, children address their talk to the doll. This caregiver-child interaction through a doll may lead children to facilitate the development of mentalization.

The third finding is that in the measurement channel above TPJ (temporoparietal junction) and mPFC (medial prefrontal cortex) regions, the oxy-Hb concentration in the helping condition was more increased in the low group than the high group. This finding tells us that children in the low group are more sensitive to other's helping behaviors and feelings than the high group. It can be interpreted that children in the high group have seen a variety of helping scenes in doll-play. In contrast, children in the low group may not be as familiar. As the helping condition requires children in the low group to mentalize others feelings, the oxy-Hb concentration was more increased in TPJ and mPFC than children in the high group.

Contrary to our expectation, we did not find any difference in the oxy-Hb concentration in the hindering condition. This may be because it is too hard for children aged 2 to 3 to understand the situation in video clips as a hindering situation. Also, unlike the helping condition, the stories of the hindering condition do not have clear ending in the sense that the issue of the hindered person still remains. Thus, different time windows to measures brain activity may need for hindering and helping conditions respectively.

In conclusion, the current study showed that the experience in playing with a doll is related to the development of mentalization, and that maternal inputs toward her child and child's response toward a doll play important roles in the development of mentalization.

There are three directions of future studies. First, the current study used only audiovisual stimuli presenting helping/hindering behaviors to see the relationship between mentalization and doll play. But role-play is comprised of different elements such as verbal and nonverbal interaction, theory of mind, mentalization, sharing and reading intention, and object manipulation (Lillard, 2017). Thus, as a future task, it is important to examine whether and how doll play affects other social, linguistic, or cognitive process by using other stimuli that are sensitive to those domains. The second future task would be conducting longitudinal studies. Sachet and Mottweiler (2013) pointed out that it has remained unclear whether engaging in role-play enhances children's social understanding or the other way around. To make the cause-effect relationship between doll-play and social understanding clear, we need to longitudinally examine the developmental path of social understanding including mentalization and how caregiver's input and other environmental resources affect children's behaviors. Finally, given that play is a culturally constructed activity (Gaskins, 2013), it is important to examine whether findings in the current study holds true for populations with other demographics (e.g., different social-economic status, people with non-Japanese backgrounds, mother-son or father-child dyads).

Acknowledgments

This work was supported by contract research grant from INFER Co., Ltd. and Japan Science and Technology Agency CREST (JP- MJCR14E2).

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