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R E S E A R C H

INTER-BRAIN SYNCHRONIZATION IN THE CLIENT-THERAPIST RELATIONSHIP DURING SANDPLAY THERAPY: AN EXPLORATORY STUDY

Michiko Akimoto[1], Hiroshi Ishihara[2], Junko Ito[3], Takuma Tanaka[4], Yasutaka Kubota[5], and Keiichi Narita[6]

1 Toyo Eiwa University, Kanagawa, Japan, ORCID ID *0000-0002-6004-4131*

2 Shimane University, Shimane, Japan

3 Saitama Institute of Technology, Saitama, Japan

4 Shiga University, Shiga, Japan, ORCID ID *0000-0003-1898-8064*

5 Shiga University, Shiga, Japan, ORCID ID *0000-0003-3482-9629*

6 Kyoto University Graduate School of Medicine, Kyoto, Japan

From the early 2000s, there have been suggestions that neuroscience may shed a new light on the healing mechanisms of sandplay therapy (Freedle, 2007; Badenoch, 2008, Punnett, 2009). As such, models on the effects of sandplay on the brain (Freedle, 2007; Badenoch, 2008) have developed. For example, Freedle (2007, 2019) discovered a pattern in the individual process of adults with traumatic brain injury and coined the term *sandplay's sensory feedback loop.* "By experiencing sandplay through the senses (e.g., seeing, touching, doing), participants became directly connected to their bodies, feelings, and creative energies" (Freedle, 2019, p.94). Badenoch (2008) described the process of sandplay therapy from the perspective of interpersonal neurobiology (Siegel, 1999). The model posits that sandplay, which begins with obtaining sensory information by touching and seeing sand, would lead to vertical integration of the body and mind, and eventually lead to the integration of both hemispheres of the brain. Emerging neuroimaging studies have found some support for these theories. For example, improvement in thalamus functioning was found in a single-case study after sandplay therapy, implicating the multi-sensory aspects of sandplay as an underlying mechanism for change (Foo et al., 2020). Studies have also found synchronization in frontotemporal networks during sandplay therapy (Akimoto et al., 2018), as well as improvements in metabolic functioning of the prefrontal cortex after a course of sandplay therapy (Foo and Pratiwi, 2021), also suggesting involvement of the prefrontal cortex as a potential mechanism of change.

In sandplay therapy, the client-therapist relationship is important. This study asks whether it is possible to demonstrate neuroscientifically how the therapeutic *relationship* specifically

Correspondence concerning this article should be addressed to Michiko Akimoto at makimoto@toyoeiwa.ac.jp

works. There has been a body of research on social interaction in the field of social cognitive neuroscience. Social interaction is, according to De Jaegher et al. (2010), "a co-regulated coupling between at least two autonomous agents," where co-regulation and the coupling have mutual impact. The process of mutual impact becomes an autonomous, self-sustaining organization which occurs in relationships, such as conversations, collaborative work, arguments, collective action, and dancing. Sandplay therapy can be regarded as a kind of social interaction, a collaborative work of the client and therapist. From this perspective, we will explore how social interactions have been studied in social cognitive neuroscience.

Studies on Social Interaction: Hyperscanning Research

A relatively new neuroimaging method of *hyperscanning*, which is a simultaneous measurement of the brain activities of two or more persons (Montague, 2002), has enabled the research on social interaction or "relationship." Measurement tools include functional magnetic resonance imaging (fMRI), electroencephalography (EEG) (Dumas et al., 2010; Müller et al., 2018), and functional near-infrared spectroscopy (fNIRS) or near-infrared spectroscopy (NIRS) (Nozawa et al. 2016; Liu et al. 2017; Fishburn et al., 2018). These studies have found interbrain synchronization between partners and within groups with good communication or collaboration. Among these brain imaging techniques, fNIRS (hereafter referred to as NIRS) measures cerebral hemoglobin (Hb) concentration changes that reflect changes in regional blood flow (rCBF) coupled with neuronal activity (Hoshi et al., 2011), which changes with time as a person thinks or feels. NIRS studies of social interaction include measuring brain activity during the communication of emotional content by drumming (Rojiani et al., 2018), rhythmic movement (Cross et al, 2016), violin duets (Vanzella et al., 2019), storytelling and listening (Liu et al., 2017), and working on a tangram puzzle together (Fishburn et al., 2018). As for psychotherapy, Zhang et al. (2018) explored interbrain synchronization (IBS) between clients and counselors and found increased IBS in the right temporoparietal junction, which is said to be related to mentalizing or empathy, during psychological counseling sessions (versus chatting). The IBS was also related to the affective bond between the counselor and client. Later the same authors also found that the IBS is stronger with experienced counselors (Zhang et al., 2020). Therefore, IBS may signify therapeutic alliance based on empathy.

Hyperscanning and Sandplay Therapy

Based on the theory and techniques of social neurocognitive science, we have been studying the brain activity of sandplay therapists and clients in simulated sandplay sessions with NIRS-based hyperscanning. In our prior 20-channel NIRS study with five client-therapist pairs, significant correlations or IBS were found in the lateral prefrontal cortex (LPFC) and the frontopolar cortex (FP) during the sandplay condition, and a significant correlation was observed only in the FP during the post-sandplay interview condition (Akimoto et al., 2021). The LPFC is involved in the executive functions, inhibition of reflex or automatic actions, and elaboration or control of goal-directed behaviors (Azuar et al., 2013), while the FP region is related to generating thoughts, making hypotheses, and evaluating them (Christoff & Gabrieli, 2000). Thus, an interview may involve synchronization of thoughts, while sandplay therapy appears to have additionally activated functions geared toward goal-directed behavior. Positive correlations in the FP were observed in previous studies with verbal interactions (Suda et al., 2010; Nozawa et al., 2016). We, therefore, considered that these brain areas of the client and the therapist are coupled during sandplay differently than verbal interactions. It may be that the negative correlation between the brain activity of the client and that of the therapist indicates that the therapist responds to the client's actions with a certain delay. Although when we focused on the sandplayer (client) alone, we found that the prefrontal and temporal cortices worked in collaboration during sandplay to reconstruct retrieved memories in the sand tray with optimal top-down, executive control (Akimoto et al., 2018). When we examined the inter-brain correlation between client and therapist pairs, no significant results were found in the temporal cortices. Therefore, as we planned for this study, we chose not to focus on this region. Also, the relationship between the interbrain synchronization and specific behaviors of the clients and therapists were not clear, as qualitative content analysis was not conducted. Moreover, the multi-channel NIRS device was rather heavy and imposed pressure on the participants' heads.

Purpose of this Study

In our effort to accumulate more data, we limited our focus to the prefrontal region. With a general objective to describe the dynamic relationship between the client and therapist in terms of IBS in the prefrontal cortex, we have been conducting NIRS-based hyperscanning on client-therapist pairs during sandplay sessions and post-sandplay interviews. We have been using a wearable two-channel NIRS device that imposes little burden on the participants and allows more natural behavior. We hypothesized that IBS between the client and therapist corresponds to clinically significant events during sandplay and the post-sandplay interview.

In this study, we examined the inter-brain synchronization of a single client-therapist pair using both quantitative and qualitative data. We investigated the following questions: (1) Will IBS increase during time segments when clinically important events occur? Conversely, (2) What is happening when IBS is high, and there are apparently no clinically important events occurring? We expected that comparing these results from the two perspectives would enrich our findings on the relationship between behavior and IBS in sandplay therapy.

Method

Participants

The client was a 20-year-old healthy female college student with good hearing and vision and without prior history of neurological and psychiatric disorders. She volunteered as a participant in response to the recruitment announcement during a psychology class. The therapist was a 42-year-old male clinical psychologist, researcher, and second author of this paper. His experience spans 20 years in psychotherapy practice, which includes sandplay therapy.

Procedure

Phases

We created a procedure with three distinct phases:

Simulated sandplay– In the first phase of this study, a simulated sandplay therapy session took place with the volunteer client and therapist. After thoroughly explaining the objective and procedures of the experiment, oral and written informed consent was obtained from the client and therapist.

In preparation for the session, two adjustable laptop desks were placed on a table, after which a sand tray (480mm x 390mm x 60mm) was placed on the desks so that the client did not need to tilt her head down, which would have increased regional cerebral blood flow while working on the sand tray. The sand in the sand tray was slightly wet. Miniature toys (e.g., trees, flowers, doll figures, animals, houses, and other architectural structures, furniture, and items related to water, such as bridges and coral reefs) were placed on the left and right sides of the sand tray. Due to the one-time, experimental, and non-clinical nature of the session, miniature toys which were likely to induce strong anxiety, were excluded.

During this part of the study, both client and therapist wore NIRS devices on their heads to simultaneously record changes of cortical hemoglobin concentration (i.e., regional cerebral blood flow). The therapist was requested to stand still with his back close against the wall and to refrain from moving his head so as not to interfere with the brain hemodynamics. The entire session was recorded using a video camera (Handycam HDR-CX680, Sony).

The therapist introduced the sand tray and provided the client with instructions on making a sandplay picture, according to the model practiced in Kalffian sandplay. After a baseline period of 30 seconds, the client made a sandplay picture within ten minutes. During this time, the therapist made no verbal comments to the client. This phase of the experiment was videotaped and NIRS recording took place for both client and therapist.

Therapist interview of client– In the second part of the study, after completion of the sandplay picture, the therapist conducted a semi-structured interview with the volunteer client about the client's thoughts and feelings that occurred as she made the sandplay picture. This interview lasted for about twelve minutes. Both therapist and client were seated for this portion of the study. NIRS recording took place for both client and therapist, and this part of the study was also videotaped.

Therapist introspection– After the first two parts of the experiment were completed, the therapist wrote down the thoughts and feelings he recalled having during the sandplay and the interview parts of the experiment, as well as those that occurred to him later during the data interpretation phase of the study. This introspection added to qualitative portion of the study and was coordinated with quantitative brain wave measurements. This introspection was recorded in writing only and was not videotaped; nor was the therapist's brain activity recorded in this part of the study.

Measurement of brain activity

The brain activity of both therapist and client was measured in the sandplay and the post-sandplay interview conditions. Two wearable and wireless two-channel NIRS (HOT-2000, Hitachi High-Technologies, Japan, https://neu-brains.site/) devices were used to simultaneously measure the prefrontal neural activities of both participants. The hemodynamics of two areas, namely, Ch1 in the left PFC region (approximately corresponding to Brodmann Area 46) and Ch 2 which covers the bilateral medial PFCs and the right FP region (corresponding to Brodmann Area 9 and possibly 10) were measured by placing the NIRS probes on the foreheads of the participants. The light source of the NIRS device uses only a single wavelength of 810 nm. As an indicator of regional blood flow, the device yields the change in the concentration of total hemoglobin (total Hb). To reduce artifacts, a band-pass filter with cutoff values of .01 and 1 Hz was applied to the raw time series of the total Hb. Thus, the remaining signals were considered to reflect brain activity.

Selection of Moments of Interest (MOIs)

The three authors of this study independently watched the recorded videos and each selected three moments of interest (MOIs) (Fachner et al., 2019) for both the sandplay and the interview, which they considered of special importance from the therapeutic perspective. All three raters are sandplay therapists and researchers. The therapist was included as one of the raters to provide a first-person perspective. Two periods in the sandplay session and three periods in the interview were identified as MOIs after agreement between two out of the three raters. The time periods for MOIs lasted from the earliest beginning to the latest end of the MOIs selected by the raters. For example, if one rater selected the time interval 5:55:08 – 7:11:80, another rater selected the period 5:58:00 – 6:36:00, and still the other selected the period the period 6:48:00 – 7:12:03, the MOI was determined as 5:55:08 – 7:12:03.

Combining quantitative data (NIRS measurement) with qualitative

Verbal transcripts of the video-recorded sandplay (approximately 10 min.) and interview sessions (approximately 12 min.) were annotated using ELAN (Version 6.1, The Language Archive Max Planck Institute for Psycholinguistics, https://archive.mpi.nl/tla/elan). ELAN is an annotation tool for audio and video recordings, which can add an unlimited number of textual annotations to audio and/or video recordings. Annotations were created on multiple layers, or *tiers* (e.g., recording channels of total Hb values and the strength of the correlation between client and therapist total Hb values, represented in colors, behaviors of the client and therapist, and the transcriptions of their utterances) which were hierarchically interconnected. The annotations were time-aligned to the videotape. This provided several ways to view the annotations since each view is connected to and synchronized with the videotape timeline.

The time series of the total Hb values of the client and therapist in Ch 1 and Ch 2 for the sandplay and interview were imported into the ELAN program, as well as the locations of the MOIs. In addition, the range of intervals, where the correlation between the client and therapist was > 0.3 or < –0.3 was also inputted to render visibility to the relationship between the behavior in the videos and the variation in the total Hb levels (Note: For time series data showing changes in total Hb concentration, there are no clear criteria for determining the strength of the correlation. Therefore, for convenience, we chose the absolute value, $|r| > 0.3$ to see the pattern of changes in brain activity associated with the sandplay and interview processes).

Correlation analysis

In order to examine whether IBS increased during time segments where clinically important events occurred (MOIs) and what events occurred during other time segments where IBS increased, Pearson's correlation between the total Hb values of client and therapist was calculated for each 50-second time window, staggered by 0.1 second (e.g., 0 s-50 s, 0.1 s-50.1 s, 0.2 s-50.2 s, etc.) for the entire NIRS time series data on sandplay and the interview. We compared Hb correlations for the client and therapist on each MOI. Additionally, we looked at time segments in which the correlation was particularly high that did not occur during the MOIs.

Results

Sandplay picture and production sequence

Figure 1 presents the completed sandplay picture, and Figure 1, detail is a close-up of the lower right part of the sand tray. The client created the sandplay picture in the following order: (1) moved the sand and made a river; (2) placed a bridge over the river; (3) planted a fruit tree and flowers; (4) placed a hedge on the sand; (5). placed a lighthouse; (6) placed seashells; (7) placed a house; (8) placed a table on the sand, put a coffee cup on the table, and placed a chair by the table; (9) placed a boat on the water; (10) put Mei (a figure in the Ghibli movie *My Neighbor Totoro*) on the chair; (11) touched Satsuki (sister of Mei in *My Neighbor Totoro*) for a moment and stopped; (12) placed Totoro on the left-side chair (Figure 1, detail); (13) turned Totoro toward Mei (Figure 1, detail); (14) placed a chicken, a dog, a flower, and a duck; and (15) placed two white wooden sticks in the upper right corner.

Figure 1, see color plate.

Figure 1, detail.

Selected Moments of Interest (MOIs)

Table 1 shows the selected sandplay and Interview MOIs, the start time, end time and corresponding behaviors of the client and therapist.

Table 1: *Selected Moments of Interest*

Moment of Interest (MOI)	**Start time**	**End time**	**Behaviors of Client (Cl) and Therapist (Th)**
Sandplay			
Sandplay MOI 1	0:37:03	1:52:06	The Cl moved the sand and made a river.
Sandplay MOI 2	5:55:08	7:12:03	The Cl placed a table and two chairs and placed Mei and Totoro on the chairs.
Post-sandplay Interview			
Interview MOI 1	4:45:02	6:07:07	Conversation regarding the Cl placing the table, chairs, Mei, and Totoro. Cl: "Mei likes Totoro."
Interview MOI 2	7:01:04	8:05:00	Discussion over the lighthouse. Cl: "Together, they are looking at it."
Interview MOI 3	8:05:07	9:08:09	Th: "Did any new ideas emerge while making the sand tray?" Cl: "In the beginning, I did not think of using the table, chairs, Mei, and Totoro. The image came up as I went on."

Client-therapist correlations during the sandplay session

Figures 2 a and 2 b contain the same data in the same format. Both figures describe events in the sandplay phase. Each figure graphs the total Hb values of both the therapist and client on 2 channels as recorded by the NIRS over the duration of the sandplay session. Sandplay Moments of Interest (MOIs) are framed in red. Below the graph, time intervals with client-therapist correlations greater than the absolute value of $|r| > 0.3$ (i.e., $r > 0.3$ or $r < -0.3$) are shown on Ch1 and Ch. These time intervals are highlighted with colored rectangles, together with the average *r* values during the time segment. The first row shows the intervals with positive correlations in Ch1. The second row shows those with negative correlations in Ch 1. The third row shows positive correlations in Ch2, and the fourth row shows negative correlations in Ch2.

Figure 2 a (see color plate) adds pictures of the client's behavior while building the sandplay picture at the two moments of interest. Figure 2 b (see color plate) highlights strong positive correlations of greater than r= 0.4 (in the peach-colored boxes) and strong negative correlations greater than r= –0.4 (in the purple boxes), regardless of the Moments of Interest. The specific behaviors of the client are written in the blue chart in the bottom part of Figure 2 b. The numbered time interval boxes in Figure 2 b correspond to the behaviors of the client listed in the blue chart.

Figure 2 a shows that the correlation between the client and therapist was particularly high in the sandplay MOIs in Ch 1 (maximum *r* above 0.8, red and orange rectangle), during which the client moved the sand and made a river. At the end of sandplay MOI 1, when most of the river had been shaped, the correlation decreased to $r > 0.3$ (light green rectangle). In contrast, on Ch 2, a positive correlation ($r > 0.3$, dark green rectangle) was noted in the latter half of sandplay MOI 1. For sandplay MOI 2, on the other hand, in Channel 1 the correlation turned from negative ($r < -0.3$, rectangle in light blue) to positive ($r > 0.3$, dark green rectangle), while in Ch 2, the correlation remained positive ($r > 0.4$, rectangle in light green, or > 0.3, dark green rectangle).

In Figure 2 b, which looks at time segments other than MOIs, the total Hb values of the client and therapist in Ch 1 were positively correlated in time segment ③ and negatively correlated in time segment ②. Alternatively, in Ch 2, time segment ④ exhibited positive correlations and time segment ② showed negative correlations. Time segment ① shows that the correlation between the brain activity of the client and therapist in Ch 1 remained greater than 0.4 for about a minute after making the river during sandplay MOI 1. Moreover, time segments ⑤ and ⑥ ($r > 0.4$) overlapped with sandplay MOI 2, but only slightly, whereas the remainder of the correlations in MOI 2 were between 0.3 and 0.4. Other intervals pointing to relatively strong positive or negative correlations ($|r| > 0.5$), such as ④, ⑧, ⑨, and ⑪, did not overlap with any of the sandplay MOIs.

Besides the strong positive correlation ($r > 0.8$) shown in sandplay MOI 1, a relatively strong positive correlation ($r > 0.5$) was observed in Ch 2 in segment ④. A large part of this interval overlaps with ② in Ch 1, where also a positive correlation ($r > 0.4$) was found. A scrutiny of this part revealed that the pattern of the changes of the total

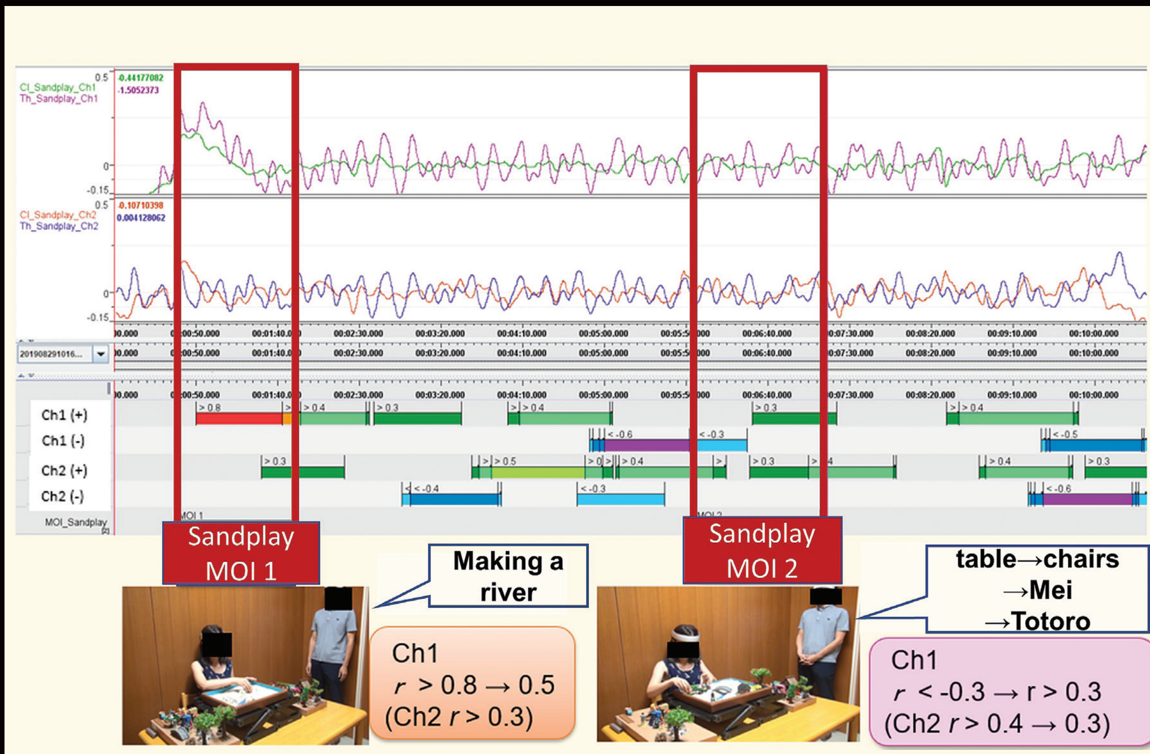
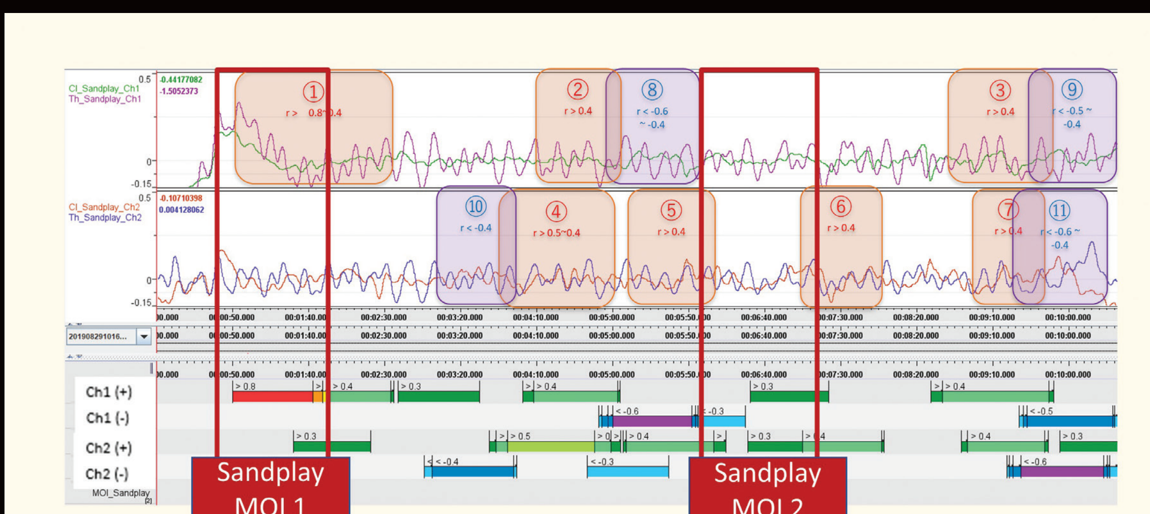


Figure 2 a – Correlations within MOIs. Also see https://www.sandplay.org/journal/research-articles/

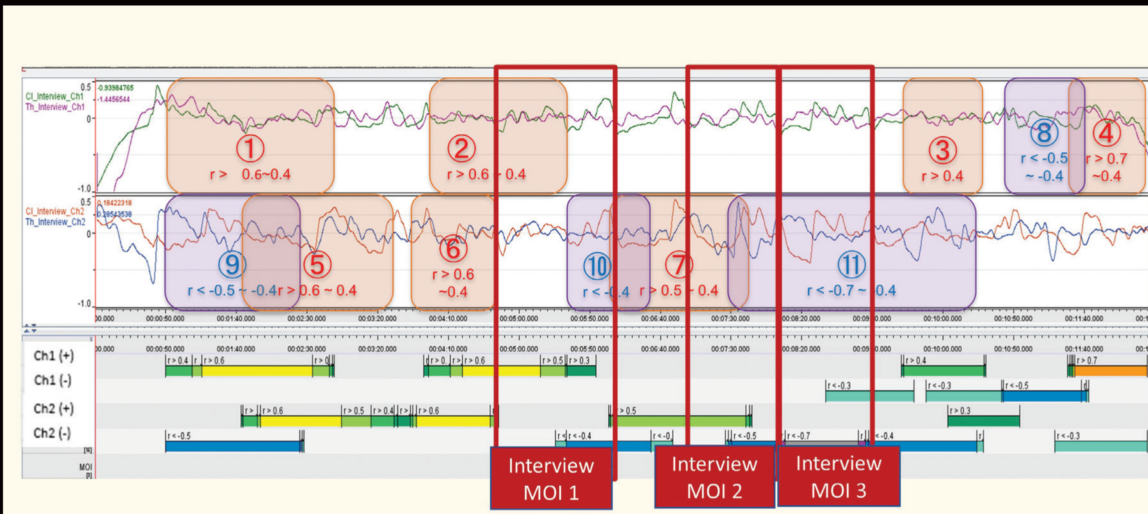


No.	Channel	r	Bahavior of the Client (Cl) and/or Therapist (Th)
①	Ch1	> 0.8 - 0.4	Moved the sand, made a river, placed a bridge over the river, and placed a tree in the upper left corner of the sandbox.
②	Ch1	> 0.4	Placed a light house and seashells in the upper right corner and browsed miniature items.
③	Ch1	> 0.4	Placed a dog in the upper center part, planted red flowers, and placed a duck.
④	Ch2	> 0.5 - 0.4	Leveled the sand, placed a lighthouse and seashells in the upper right corner, and browsed items.

区間	Channel	r	Bahavior of Cl and/or Th
⑤	Ch2	> 0.4	Placed a house and a goat. Browsed items, brushed off the sand from the hands, picked up a coffee cup and a table and placed the table in the lower right corner.
⑥	Ch2	> 0.4	Placed Totoro on a chair, adjusted the angle of the chair, placed a tree in the left, and browsed items.
⑦	Ch2	> 0.4	Placed red flowers in the lower right part and placed a duck.

No.	Channel	r	Bahavior of Cl and/or Th
⑧	Ch1	< -0.6 - -0.4	Browsed items, placed a house in the center, placed a goat, and browsed items while brushing the sand off the hands.
⑨	Ch1	< -0.5 - -0.4	Placed a duck, browsed items while leveling the sand, and placed white wooden poles on the right side.
⑩	Ch2	< -0.4	Placed flowers on the left of a tree, picked up a hedge and placed it in the lower right part while leveling the sand.
⑪	Ch2	< -0.6 - -0.4	Browsed items, placed a duck, browsed items while leveling the sand, and placed wooden poles in the right side.

Figure 2 b – Correlations within notable time segments and chart below showing behavior. Also see https://www.sandplay.org/journal/research-articles/



No.	Channel	r	Bahavior of Client (Cl) and/or Therapist (Th)
①	Ch1	> 0.6 - 0.4	What the Cl thought about her sand tray, what she planned to make, and what she was thinking when she moved the sand.
②	Ch1	> 0.6 - 0.4	On using the bridge, the table and chairs, and Mei and Totoro in the sand tray.
③	Ch1	> 0.4	What part of the sand tray felt right to the Cl and what did not feel right to her.
④	Ch1	> 0.7 ~ 0.4	On the limitation of the time available for sandplay and any other thoughts on this sandplay

No.	Chan nel	r	Bahavior of Client (Cl) and/or Therapist (Th)
⑤	Ch2	> 0.6 - 0.4	What the Cl made, what she was thinking when she moved the sand, on the shape of the pond (or the sea)
⑥	Ch2	> 0.6 - 0.4	On the shape of the pond (or the sea) and on placing the bridge
⑦	Ch2	> 0.5- 0.4	On placing animals, parts the Cl elaborated on, and on the lighthouse

No.	Channel	r	Bahavior of Client (Cl) and/or Therapist (Th)
⑧	Ch1	< -0.5 - -0.4	Any other comments and comments on the limitation of time
⑨	Ch2	< -0.5 - -0.4	What the Cl thought about her sand tray, what she planned to make, and what she was thinking when she moved the sand.
⑩	Ch2	< -0.4	On Totoro and the animals
⑪	Ch2	< -0.7 - -0.4	On the lighthouse, new ideas or insights, and what the Cl thought felt right to her or what did not feel right to her

Figure 3 – Correlations during the post-sandplay interview. Also see https://www.sandplay.org/journal/research-articles/

Figure 1.

Hb of the client and therapist in Ch 2 was synchronized beautifully for approximately 20 seconds (4:19.995 – 4:39.237). The total Hb levels of the therapist seemed to increase in tandem with those of the client as the client placed three seashells rhythmically, one by one.

Client-therapist correlations during the post-sandplay interview

Figure 3 (see color plate) shows the correlations between the total Hb values of the client and therapist as they appeared over the duration of the post-sandplay interview. The three interview Moments of Interest (MOIs) are again framed in red. Time segments with positive correlations (above 0.4) are shown in peach-colored boxes; those with negative correlations (stronger than –0.4) are shown in purple boxes. The corresponding discussion topics between clients and therapist during the post-sandplay interview are shown in the blue chart in the bottom part of Figure 3. During the interview, the number of intervals with positive correlations above 0.4 (peach-colored boxes) exceeded those with negative correlations exceeding –0.4 (purple box) in Ch 1, whereas more intervals with negative correlations than positive correlations were observed in Ch 2.

In the post-sandplay interview phase of this study, none of the correlations within the MOIs were markedly higher than in the other time windows. In Interview MOI 1, when the client and therapist were talking about the client's placement of the table, chairs, Mei, and Totoro, a relatively strong positive correlation (maximum $r > 0.6$) was noted between the two in Ch 1, whereas in Ch 2, the correlation was negative ($r < -0.4$). In Interview MOI 2, where the two persons were discussing the placement of the lighthouse, a relatively strong positive correlation ($r > 0.5$) was observed in Ch 2 in the first half of this time period. However, it became negative ($r < -0.5$) in the middle. In Interview MOI 3, the correlation was negative in both Ch 1($r < -0.3$) and Ch 2 ($r < -0.7$).

Overlaps were observed in time segments ② and ⑩ in with Interview MOI 1, time segments ⑦ and ⑪ with Interview MOI 2, and interval ⑪ with Interview MOI 3. However, the starting points and the end points of the intervals were not exactly the same as those of the MOIs. Similar to what was seen in the sandplay session (Figures 2 a and b), discrepancies were noted between intervals considered clinically important and those where the correlation between the client and therapist was relatively high.

Therapist's introspections

According to the therapist's reflection on the sandplay process, during sandplay MOI 1, the therapist watched the client making a river without deliberate thinking. In contrast, during sandplay MOI 2, he was expecting the result with excitement.

Later, in his reflection on the post-sandplay interview, he considered Interview MOI 1 to be the most important interaction of the interview. During this time, he was listening to the client with much enthusiasm and expectation. However, he thought that the client's narrative was relatively terse and fell a bit short of his expectation. This terse narrative occurred in the latter half of the interaction, where anti-phase synchronization (i.e., negative synchronization) was observed. In Interview MOI 2, the client talked about the time when she placed the lighthouse. However, the therapist was confused because the timing of the lighthouse placement differed from that of the therapist's memory. This occurred in the second half of Interview MOI 2 which also showed a negative correlation. It is possible that this confusion continued into Interview MOI 3.

Discussion

The present study is the first to use the portable NIRS to examine the inter-brain synchronization (IBS) between the client and therapist during sandplay. In a mixed-method analysis that integrated quantitative data (NIRS measurements) and qualitative data (behavioral data on video, client interview by therapist, as well as a subjective reflection by the therapist), we examined relationships between the changes of IBS and the behaviors of the client and therapist. Specifically, we identified sandplay Moments of Interest (MOIs) and Interview MOIs from ELAN data and closely investigated the corresponding IBS changes in comparison with other periods during the sandplay and interview. Furthermore, we analyzed the relationship between IBS and the behavior of the client and therapist.

Brain synchronization during Moments of Interest (MOIs)

When we focused on the MOIs on Ch1 of the sandplay MOI 1, when the client moved the sand and made a river, showed higher brain synchronization than the other time windows. During this time, the client's dynamic action to split the whole sand tray into two determined the basic structure of the scene. Watching this, the therapist might have become entrained by mentally mirroring the client's movement into the co-creation of the landscape. However, the result needs to be interpreted with caution because the correlation might become artificially high when two time series data show a steady trend of change or low frequency (i.e., slow wave) fluctuation. In the interview condition, none of the three MOIs showed significantly increased IBS compared to the other intervals. The exception to this occurred in Interview MOI 3 when the correlation in Ch 2 exceeded –0.7. At that time the therapist reported confusion.

Other relatively highly correlated time intervals

Although there is no absolute standard for high and low correlations with respect to time series such as our NIRS data, there were intervals with relatively high correlations outside the MOIs. When we tentatively focused on $|r| > 0.4$, Channel 1 in the Sandplay condition showed five intervals with either positive or negative correlations above this arbitrary cutting point. Sandplay Channel 2 showed six such intervals. During the Interview condition, Channel 1 showed five intervals beyond this cutting point and Channel 2 exhibited six.

This suggests that the client and therapist were synchronizing, as far as the measured brain regions are concerned, but not necessarily during moments that were identified as important. According to mirror neuron theory (Rizzolatti & Craighero, 2004), seeing another person's action "evokes a neural activity that corresponds to that which, when internally generated, represents a certain action" (Rizzolatti et al., 1999, p.98), which is considered to be a basis of empathy (Rizzolatti, & Craighero, 2004). The theory has also been extended to "embodied simulation", a theory stating that mental states or processes are embodied because of their physical format (Gallese, 2007). In sandplay, the client and therapist do not move their hands together, but the movements of the client's hand(s) (Gallese, 2007; 2019; Balfour, 2013) can trigger mental representations in the therapist's mind, so that the therapist experiences, mentally and perhaps unconsciously, making the sandplay picture together with the client. According to Balfour (2013), such sharing of the sandplay experience, especially its "shared neural unconscious space," activates the therapist's empathy, which in turn enables the patient to grasp a different kind of relationship never experienced before" (p.112). Thus, in sandplay therapy, repeatedly watching clients perform actions with their hands, including seemingly unimportant ones, may contribute to the basis of the client-therapist relationship. It is possible that the two frontal brain regions we measured in this study (the lateral prefrontal cortex and the frontopolar cortex) may work together to create a dynamic interaction between client and therapist.

Functional differences of the brain regions and sandplay therapy

According to previous studies (Ikeda et al., 2017; Nozawa et al., 2019), the lateral prefrontal cortex (LPFC), which roughly corresponds to Channel 1 in our study, is responsible for externally-oriented thinking, while the frontopolar region (FP/mPFC) which approximately corresponds to Channel 2, is related to internally-oriented thinking, that is, such as introspection, mentalizing, or predicting the other's states. It is suggested from our results that Ch 1 may be associated with the outwardly visible and comprehensible behavior of constructing the scene, while Ch 2 may be associated with reflection and prediction of what to do next. During the Interview phase, Ch1 of both the client and therapist remained activated, probably because the client and therapist used their executive functions, including attention and working memory (Azuar et al., 2013), to respond appropriately to the other's questions and answers, such that a coherent dialog could be established. The values in Ch 2 may have fluctuated according to whether one is a speaker or a listener in a conversational turn-taking, which possibly leads to anti-phase synchronization (i.e., stronger negative correlation).

Limitations and suggestions for future research

Since this study focuses on a single case in a controlled sandplay setting, the results can only be generalizable through further accumulation of data. Precise interpretations will be only possible by comparing the results across other client-therapist pairs. We do not yet know exactly what positive correlation and negative correlation mean in terms of client-therapist interaction during sandplay. It is noted that in our prior study (Akimoto et al., 2021), we attributed the negative correlation to the time gap in image processing between clients and therapists. More case studies with detailed analyses would also help to determine differential functions that various brain areas perform. Moreover, by using a larger sample size, future studies may also be used to determine the optimal amount of synchronization or desynchronization.

The full meaning of the correlation values presented in this study remains unclear due to the current lack of knowledge about what constitutes optimal synchronization. Additionally, the measurement targeted only two PFC channels, although sandplay and interview entail much wider and cortical and subcortical areas of the brain. As a result, the study focused on top-down, cognitive processes. Given the highly emotional nature of sandplay therapy, examining other regions such as the limbic system or the insula is desirable for future studies. However, since sandplay requires a high level of cognitive processing for the client, engaging in tandem in cognitive tasks with the client can be one basis of empathy for the therapist. Thus, the authors believe that examining the PFC (LPFC and FP) functions is important.

The multiple roles of the therapist as researcher, interviewer, recaller, and MOI selector might also be problematic, since the therapists' other roles may have subtly influenced the result of this experiment. Nevertheless, sandplay therapy research to date has often used a therapist-researcher model, and some additional insights may be gained from a first person experience as it is employed, for instance, in participant-observer research. Additionally, it is very difficult, if not impossible, in a single case study in which all researchers are intensely involved, to conduct any blind interpretation of the data. However, future studies may wish to identify MOIs with stricter criteria than simply therapist/researchers' clinical intuition. Further issues pertaining to the therapist might be: (1) the therapist's need to stand motionless to gather NIRS readings, inhibiting the freedom of movement characteristic of clinical sandplay sessions; and (2) the fact that the therapist introspection condition was based on delayed recall only and thereby open to distortion or omission.

Finally, the present study calculated the correlation between the client and therapist at the same time points. However, a possibility exists that the two are synchronized with a lag; perhaps first the client acts (e.g., choosing a miniature and placing it in the sand tray) to which the therapist reacts some moments later. However, another possibility is that, in reverse, the therapist anticipates a certain action, which subtly influences the client's subsequent actions. Therefore, examining when and how the therapist leads and follows, possibly influencing the client, will be an important aspect of future studies. Future research might also further refine the methods for analyzing the complex interplay between the client and the therapist.

Conclusion

In conclusion, the detailed analysis of the client-therapist interaction during sandplay and post-sandplay interview using the mixed methods design suggests that measurement of brain activity combined with detailed examination of behavior of the client and therapist may provide a new perspective for the investigation of empathy and attunement in sandplay therapy. Although much is still unclear, our study has suggested the process of how the therapist's witnessing and contemplating the sandplay process might lead to inter-brain synchronization. In the future, by accumulating data from different client-therapist pairs and sessions and refining the experimental procedures and analysis methods, researchers may be able to explore further what is happening in the therapeutic relationship during sandplay therapy.

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