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[Original Article]

Effects of storytelling on the childhood brain : near-infrared spectroscopic comparison with the effects of picture-book reading

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Abstract

In children, storytelling provides many psychological and educational benefits, such as enhanced imagination to help visualize spoken words, improved vocabulary, and more refined communication skills. However, the brain mechanisms underlying the effects of storytelling on children are not clear. In this study, the effects of storytelling on the brains of children were assessed by using near-infrared spectroscopy (NIRS). Results indicated significant decreases of the blood flow in the bilateral prefrontal areas during picture-book reading when the subjects were familiarized in comparison to the cases of the subject naïve to the stories. However, no significant differences in the blood flow were found during storytelling between the subjects naïve and familiarized to the stories. The results indicated more sustained brain activation to storytelling in comparison with picture-book reading, suggesting possible advantages of storytelling as a psychological and educational medium in children.

Key words : Storytelling, Picture-book reading, Children, NIRS

Introduction

What is storytelling? The US-based National Storytelling Network (NSN) defines the term as follows : *Storytelling is the interactive art of using words and actions to reveal the elements and images of a story while encouraging the listener's imagination* (http://www.storytelling.org/resources/whatisstorytelling). Storytelling is the activities of humans with long history. (for the details, see[1-5]). It should be noted that storytelling is totally different from picture-book reading since storytelling is performed without the use of any printed materials, usually with frequent eye contact between the performer and the listener.

In recent years, near-infrared spectroscopy (NIRS) has gained popularity as a tool to measure the brain activities in younger children[6-8]. Previous studies using NIRS have reported the effects of picture-book reading experiences on the prefrontal activities of children, especially when the picture-book reading was given by their own mothers. However, the results so far obtained have been controversial. It was reported in a study by Haji *et al.* that, during a picture-book reading, many mothers showed increased activity in their prefrontal areas, whereas many children showed decreased activity in their own prefrontal areas[9]. On the other hand, it was shown in another report by Ohgi *et al.* that significantly greater prefrontal area activities occurred in younger children during a picture-book reading given by their own mothers,

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versus the passive-viewing of a videotape in which a story was read by a stranger[10]. In Haji's study the subjects were familiar with the performance of the picture-book reading, whereas in Ohgi's study, the subjects seem to be relatively naïve to it. This information suggests that familiarization with the performance of the picture-book reading (*see below*) might have influenced the results of those studies.

In contrast with those of picture-book reading, the neurobiological effects of storytelling on the prefrontal activities of children have never been sufficiently studied. It is intriguing that some clinical reports have suggested that the effects of storytelling on the listeners' behaviors, such as listening with an eager attitude[11], or emotional responses to the story[12], is more evident for the children who are sufficiently familiarized to the performance of the storytelling, particularly in comparison with the children who are fully naïve to the performance[13]. Familiarization with the storytelling performance, here, means that the children get used to storytelling itself, i.e., to learn how it is performed. It was therefore suggested that familiarization with the performance can be an important facilitator for the neurobiological effects of the storytelling.

In this study, to clarify the neurobiological effects of storytelling, we assessed the brain activation mainly around the prefrontal areas of children by using NIRS monitoring. We focused on three points. First, we compared the prefrontal activities during storytelling with those during picture-book reading. Second, we evaluated the effects of sufficient familiarization with the storytelling on the activities in the prefrontal areas of children. And third, we looked for the difference in brain activities between the left and right hemispheres of the brain.

Materials and Methods

Participants and ethics

The study was conducted with the approval of the Fukushima Medical University Ethics Committee (approval #827). An open invitation of public participation in the experiments were offered via brochures to any parents or guardians in Fukushima Medical University, including the university's own nursery school. As a result, 22 parents or guardians applied to the public participation. Then, in advance of the experiments, the purposes and methods of the study were explained to said parents or guardians, both verbally and in writing. It was confirmed in the explanation to the parents or guardians, with the utmost care and attention, that all participation could have been decided with free will of them. At this point, one parent decided that their child would not participate. Finally, a total of 21 healthy children, aged between 4 and 11 years old, participated in the study as subjects, 11 of whom were from the university's nursery school, and the remaining subjects were not enrolled in this nursery school. The parents and guardians of all 21 participants gave their approval for their children to participate in the present study. The participant's maturity levels were also estimated using the Social Maturity (S-M) scale (Nihon Bunka Kagaku-sha) before the NIRS experiment. The Edinburgh Handedness Inventory test was also performed to determine the handedness of each participant.

Stories, picture-books and task sessions

Table 1 lists all the stories (**A**) and picture-books (**B**) used in the experiments. For each participant, the experimenter (M.Y.), who is an experienced storyteller, picked and selected a particular story or a particular picture-book that she considered suitable for the participant. It was confirmed that the stories or the picture-books used in the NIRS experiment both in the *naïve* and *familiarized* sessions (*see below*) were ones that the participants had never been exposed to before the study ; that is to say, the participants were unfamiliar with the content of the story or the picture-book before the experiments.

The task of the storytelling or picture-book reading was given in two different sessions, i.e., a naïve session and a familiarized session. In the naïve session, the participants had no prior familiarity with the performance of the storytelling or picture-book reading (naïve sessions). In the familiarized session, the participants had sufficient prior familiarity with the performances of the storytelling or the picture-book reading, i.e., they had been subjected to previous storytelling performance or picture-book readings, but had not encountered the particular narrative in the experimental session.

Familiarization with the performances was achieved in two different ways, as depicted in **Figure 1**. Some participants who were from the nursery school were subjected to storytelling or picture-book reading sessions twice a month over a period of four months (eight visits in total) after the naïve sessions, at the nursery school, without NIRS monitoring. However, the participants who were

Table 1. Stories and picture-books used in the study

A. Story titles

Title No.	Title	Source
Story 1	Anansi And Five	Jamaican Folktale
Story 2	The Principal And The Student Monk	Japanese Folktale
Story 3	The Dark Dark House	American Folktale
Story 4	The Carrot And The Japanese Radish And The Burdock	Japanese Folktale
Story 5	The Cat And The Mouse	British Folktale
Story 6	The Marriage Of The Mice	Japanese Folktale
Story 7	The Boy Included In A Peanut	Source Unknown

B. Picture-book titles

No.	Title	Author
Picture-book 1	Good-Night, Owl !	Pat Hutchins
Picture-book 2	Tidy Titch	Pat Hutchins
Picture-book 3	The Line Up Book	Marisabina Russo
Picture-book 4	The Three Bears	Byron Barton
Picture-book 5	Shironeko Shirochan	Sachiko Mori
Picture-book 6	The Little Red Hen	Byron Barton
Picture-book 7	Willie's Walk	Margaret Wise Brown

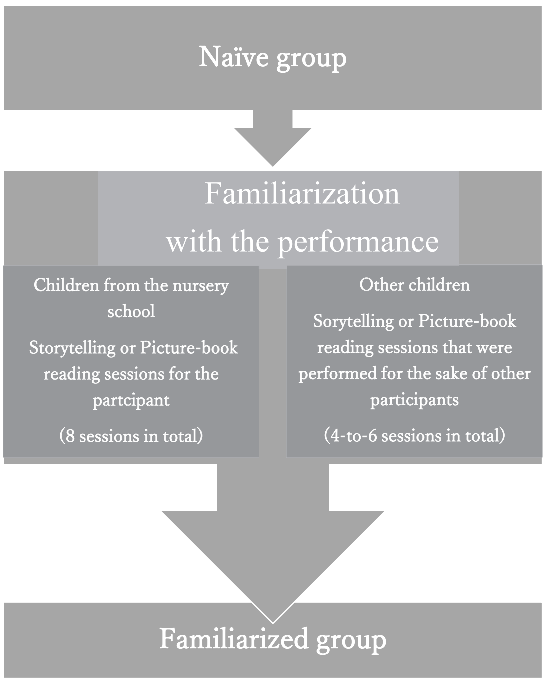

Fig. 1. Flow chart of the familiarization procedure

not from the nursery school were not subjected to this four-month preparation period of storytelling or picture-book reading. Instead, on the day of the monitoring, they were separated into groups of two or three children each, with at least 4-to-6 monitoring sessions that were performed for the sake of other participants (usually their siblings or friends) and listened to the storytelling or the picture-book reading together with the other participants. After these familiarization procedures, the participants from the nursery school and those not from the nursery school were combined in a familiarized group and subjected to the NIRS monitoring (familiarized sessions).

NIRS monitoring and data analysis

An Hitachi Medical Corporation ETG4000 Optical Topography System, which was equipped with a cluster of 15 probes placed in a 3-by-5 grid configuration using 22 channels, was used for the NIRS monitoring, as shown in **Figure 2**. The approximate locations of the probes, rendered onto the surface MR image of a subject, are also shown. Each monitoring session consisted of a baseline period and a task period. During the baseline period, the participants listened to a recitation of the 50 letters of the Japanese alphabet by the experimenter. During the task period, on the other hand, the participants listened to either storytelling or picture-book

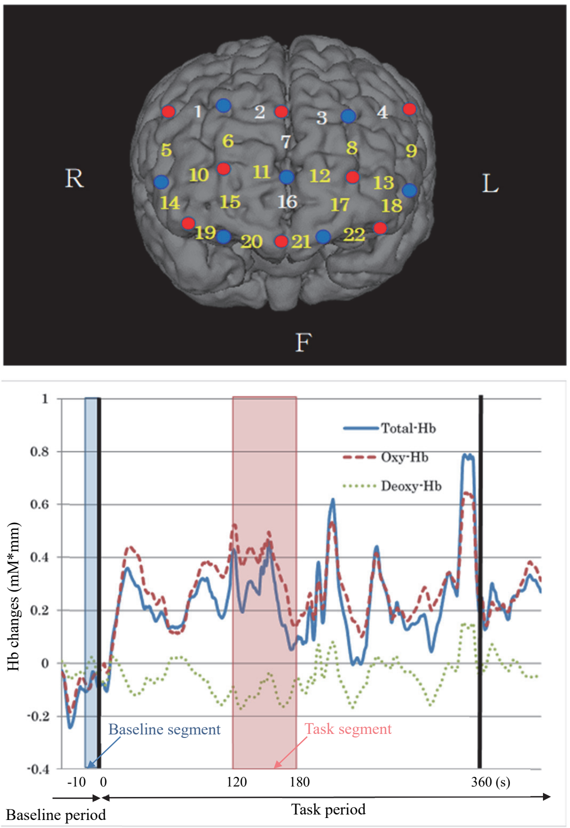

Fig. 2. NIRS monitoring and data analysis
1) Channel positions overlaid on the MRI brain-scan image of an 8-year old boy, with the head circumference of 52 centimeters. Eight emission probes (red closed circle) and seven detection probes (blue closed circles) were arranged in a 3×5 rectangular lattice. The distance between the probes was 30 mm. The channel numbers are indicated between the emission probes and the detection probes.
2) Baseline segment was the 10 seconds immediately prior to the start of the task. Task segment was the 120-to-180 second segment (60 seconds) from the task commencement.

reading conducted by the experimenter.

The raw data of the Total-Hb, Oxy-Hb and Deoxy-Hb values were obtained and normalized for the comparisons across individuals. For the normalization, we used a method similar to that used in the earlier study by Kobayashi *et al*. (2011) on face recognition in infants[14]. First, the mean (m*i*) and standard deviation (sd*i*) of Total-Hb, Oxy-Hb and Deoxy-Hb at the channel *i* during the 10-sec baseline segment which precedes the onset of the task period[15] were calculated for each individual participant. Second, the mean (M*i*) of Total-Hb, Oxy-Hb and Deoxy-Hb during the 60-sec task segment (between 120 and 180 sec) in each task period was also calculated. During this task segment, all the participants were confirmed to exhibit the least amount of body motion based on the review of their video footage recorded during the measurement. The normalized value of channel *i* (n*i*) was, then, obtained as Z-score, using the following equation :

$$ni = (Mi - mi) / sdi.$$

To eliminate noise, those channels whose absolute values were below 2.0 were rejected, and if the number of rejected channels exceeded 50%, data from that participant was removed from the subsequent data analyses.

As for statistical analyses, the measurement data originating from 16 channels out of the total of 22 – the data from the left eight and right eight channels were used while those from the upper 4 and middle 2 channels were skipped. The means over the left-most and right-most eight channels were calculated for each participant once the per-channel n*i* values were calculated. These values were then used to perform 3-way ANOVA for the following factors : 1) task difference (storytelling versus picture-book reading), 2) familiarity difference (naïve group versus familiar group), and 3) area difference (left frontal versus right frontal areas). SPSS (IBM) was used to perform these analyses.

Results

Of all 21 participants, the data obtained from six were discarded from the analysis because the participants were left-handed or their data were insufficiently sampled. Ultimately, the data obtained from the remaining 15 participants were registered for the analysis. Five were obtained in the naïve sessions, whereas 11 were obtained in the familiarized sessions. Aside from one participant, whose data were obtained both in the naïve and familiarized sessions, all data were obtained exclusively either in the naïve or familiarized sessions. In the naïve sessions, data were obtained from four participants who completed both the storytelling and picture-book reading sessions, and from one participant who completed the storytelling session only. In the familiarized sessions, data were obtained from nine participants who completed both storytelling and picture-book reading sessions, from one participant who completed the storytelling session only, and from one participant who completed the picture-book reading session only. **Table 2** lists the participants of each group, as well as the stories and picture-books presented to them. The profiles of each participant group are

Table 2. Participants and the stories and picture-book presented to them.

A. Naïve group

ID	Sex	Age (months)	First task	Second task
12	M	97	Story 7	Picture-book 3
15	M	91	Story 1	Picture-book 2
18	F	79	—	Story 6
19	M	132	Picture-book 3	Story 2
20	M	99	Picture-book 6	Story 1

B. Familiarized group

ID	Sex	Age (months)	First task	Second task
1	F	57	Story 7	—
2	F	60	Story 7	Picture-book 1
3	M	101	Story 1	Picture-book 3
5	F	63	Picture-book 7	Story 7
6	M	77	Story 1	Picture-book 6
7	F	80	Story 1	Picture-book 2
9	M	108	Picture-book 6	—
11	M	59	Picture-book 6	Story 7
12	M	103	Story 4	Picture-book 1
14	M	59	Picture-book 1	Story 7
16	M	58	Story 7	Picture-book 1

Table 3. Summary of the participant groups.

		Sex	n	Average age (months)
A. Naïve group	Storytelling	M : 4 F : 1	5	99.6±19.7
	Picture-book	M : 4 F : 0	4	104.8±18.5
B. Familiarized group	Storytelling	M : 6 F : 4	10	71.7±17.9
	Picture-book	M : 7 F : 3	10	76.8±20.3

summarized in **Table 3.**

The results of 3-way ANOVA revealed the main effect on the familiarity difference was significant (Total-Hb, Oxy-Hb : $p < 0.05$; Deoxy-Hb, *n.s.*). Neither the main effect of the task difference (storytelling versus picture-book reading) nor that of area difference (left frontal versus right frontal areas) showed any significance. As for interactions, task difference versus area difference, as well as area difference versus familiarity difference did not show any significant differences. The interaction between the task effect and familiarity effect, on the other hand, did show significant difference (**Figure 3,** Total-Hb : $p < 0.05$, Oxy-Hb : $p < 0.01$, Deoxy-Hb : *n.s.*). Further test for simple main effect revealed significant decreases in blood flow in the familiar group during picture-book reading (Total-Hb : $F(1,50) = 6.863$, $p < 0.05$, Oxy-Hb : $F(1,50)$

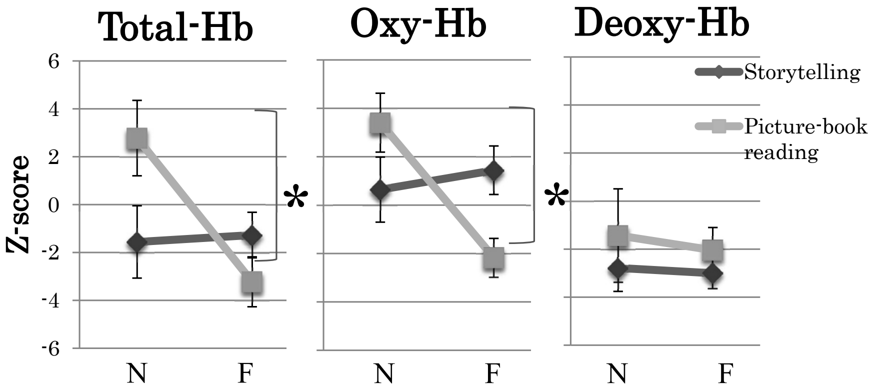

Fig. 3. Effects of task and familiarity differences on blood flow.
The simple main effect revealed significant decreases of Total-Hb and Oxy-Hb values in the familiar group during picture-book reading. (* ; < 0.05).
N : Naïve session. F : Familiarized session.

= 8.480, $p < 0.05$, Deoxy-Hb : $F(1,50) = 3.322$, *n.s.*) although no such changes were observed during storytelling. It therefore became evident that, as **Figure 3** shows, the interactions were due to the decreases in blood flow associated with the picture-book reading. Three-way interactions between task difference, familiarity difference, and area difference did not show any significance.

Discussion

Our present study showed that, the prefrontal activities were high during picture-book reading by an unfamiliar person in the naïve group, but were reduced as the subject became familiarized with the reader, implying that the familiarized picture-book reading elicits lower activation in those cortical areas of children. These results are consistent with previous studies, which reported high activities during picture-book reading given by the subject's mother in a relatively naïve condition[10], and lower activities in a familiarized condition[9].

To date, however, there have been no reports on the effects of storytelling on brain activities. The results in our present study firstly show the neurobiological effects of storytelling, indicated that storytelling had not reduced activation of the bilateral prefrontal areas, after subjects had sufficient familiarization with the process itself.

We should note that there is a substantial difference in the cognitive requirement between the experience of the picture-book reading and that of the storytelling. That is, during the picture-book reading, usually the story is passively given to listeners because the picture-book offers abundant visual information to guide the listeners' understanding. However, the experience of the storytelling requires a more demanding level of active imagination from listeners. It has been commonly hypothesized that a person listening to storytelling engages with the story by using his or her imagination as inspired by the words of the storyteller, in order to visualize the story while simultaneously forecasting what lies ahead[16,17]. Therefore, the difference in the prefrontal activation between the picture-book reading and the storytelling may reflect the difference in the cognitive demands for the act of imagining.

The results in the present study are not only consistent with the previous literature but also parallels recent claims emerging in the field of clinical education, which indicate that picture-book reading may not be as useful as once expected[18-20]. These claims are based on the notion that the abundance of visual aids provided in picture-book reading may not be useful for, and might even prevent, deployment of the imagination. In a complementary fashion, our results showed that the naïve picture-book reading activated the prefrontal areas, but the activities substantially fell after sufficient familiarization, implying that picture-book reading may be only temporally effective. In addition, it was also shown that storytelling didn't make activity of the bilateral prefrontal areas fall after sufficient familiarization, implying that the storytelling preserve activation of the prefrontal areas after the listeners have become familiarized with the storytelling. In agreement with the previous clinical claims discussed above, our results may support usefulness of storytelling in the field of clinical education.

There were some limitations to the present study. First, only the prefrontal activities were measured, because of technical reasons in the NIRS measurement for children. Involvement of other brain regions in picture-book reading and/or storytelling performance need to be clarified to further support the usefulness of storytelling. Second, we did not follow up the NIRS activation after the familiarized test. Whether the effect of familiarized storytelling can be sustained or not thereafter needs to be investigated. Finally, the number of participants was insufficiently small. For this reason, we could not statistically test the effects of the group recruitment settings, sex, age or storytelling / picture-book reading materials. Regarding investigation into the small number of subjects tested, the different materials had similar effects to the naïve / familiarized differences on the prefrontal activities. In addition, we should point out that there existed a large gap between the average ages of the two groups (99.6 ± 8.8 months versus 75.0 ± 6.1 months).

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Conflict of Interest Disclosure

The authors declare no conflicts of interest associated with this manuscript.

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