Effective Learning Material for English (L2) Assessed in Terms of Brain Activation Using Functional Near-Infrared Spectroscopy (fNIRS)

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Abstract

In this study, effective teaching method for Japanese students in tertiary English (L2) classroom lessons was assessed in terms of brain activation (BA) using functional near-infrared spectroscopy (fNIRS). The Participants performing word recognition task, listening task, oral task, and shadowing task in English (L2). Four factors presumably associated with cortical activation, the level of the target words (higher/lower), the task (listening/speaking/shadowing), and the leaner's English proficiency based on their TOEIC score (higher proficiency group/ lower proficiency group, HG/LG), were investigated. Suggestions for effective teaching/learning include choosing an appropriate word level, focusing on the target word or sentence by using spacing with blanks depending on individual proficiencies, and designing the tasks based on individual working memory (WM) capacities.

Keywords: *Effective learning method, task, proficiency level, brain activation, fNIRS.*

1. Introduction

How learners process and store linguistic information in the brain while learning second and foreign languages in the class room? A recent functional magnetic resonance imaging (fMRI) study examined brain structures in Japanese L2 school students studying English and revealed a significant correlation between the performance on a syntactic task and leftward lateralization in a single region in the triangular part (F3t) of the inferior frontal gyrus (IFG), which has been proposed as the grammar center [1].

WM represents the immediate memory processes involved in the simultaneous storage and processing of information [2]. To measure WM capacity, reading span test (RST) was developed. An excellent reader has more WM capacity to store information during text reading, which is significant correlation with reading comprehension scores [3]. Osaka et al. [4] measured WM capacity using an RST written in Japanese and English (English-as-a-second-language version), and found that the Japanese and ESL versions were highly correlated.

The noninvasive and continuous measurement of BA with functional near-infrared spectroscopy (fNIRS) was introduced over 20 years ago. A major advantage of fNIRS over other neuroimaging techniques is its compact measurement system that put less strains on participants, and this technique is less sensitive to motion artifacts [4], enabling its use in various experimental settings [5][6]. Using fNIRS, functional BA is measured noninvasively by recording changes in oxygenated and deoxygenated hemoglobin (HB) concentrations. The use of fNIRS has been advanced by validation studies using fMRI and fNIRS simultaneously, suggesting that these approaches are correlated across key visual WM regions in front-parietal network [7].

In the present study we conducted the experiment to explore the activation of Japanese L2 college students' brain depending on the factors such as degree of difficulty of the target word (higher/lower), task (closed/unclosed/target words blanked), learner's English proficiency (higher/lower) by using fNIRS (LIGHTNIRS, Shimadzu Corporation, Kyoto, Japan) while learning English.

2. Material and Methods

2.1 Participants

The present sutudy involved 16 healty college male students who are all right handed and aged 21.8 on average. The participants were divided into two English proficiency groups, i.e., a higher score group and a lower score group (HG and LG, respectively), based on their TOEIC test scores. The average sore of HG (n = 8) was 574.4, while that of LG (n = 8) was 441.6; there was a significant difference in TOEIC scores between the two groups (*p <.01).

2.2 Data Acquisition – fNIRS

fNIRS data was obtained using a multichannel spectrometer (LIGHTNIRS, Shimadzu Corporation, Kyoto, Japan). A 2x4 array of optoded consisting of 8 laser diodes and 8 light detectors, alternately placed at interoptode didtance of 3 cm to yeild 2 channels, was applied on each side of the participants's heads by matching the center of the lower row to T3 (left) and T4 (right) position of the international 10/20 system (Fig.1). The changes in oxygenated [oxy-Hb], deoxygenated [deoxy-Hb], and total hemoglobin [total-Hb] signals were caluculated, and the optical signal were sampled at a rate of 14 Hz.

2.3 Experimental Tasks

The following four types of tasks were peformed by each participant in two groups (HG and LG) in the fNIRS experiments as follows: word recognition task with the words from higher level and lower level of CEFR, (C2 and A1), (WRH and WRL); listening task with unclosed script, closed script, and sentences with target words blanked (LU, LC, and LB); oral (O) task with script unclosed, closed, and with target words blanked (OU, OC, and OB); shadowing task with the sctript unclosed or closed (ShU and ShC). During the RA session, the participants first listen to the dialog with A and B and then they take the part B orally. In shadowing, participants first listen to the sound and start shadowing (LshU and LShC). The stimulus in black letters against a white background was presented visually at the center of the screen. The stimulus presentation was controlled using the PPT2TTL software (WAWON DIGITECH Corporation). For fixation, a black cross was shown at the center of the screen for 30 s at the beginning of each task, direction in Japanese of the task was shown for 20 s, then each stimuli was shown for 20 or 30 s.

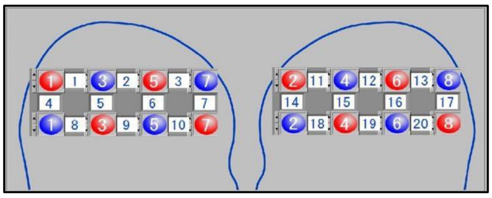

Fig.1 Close view of the fNIRS equipment and the location of the 20 channels.

3. Results and Discussion

3.1 Word Recognition (WR) Task

There was no significant difference in BA in WRL between two groups (Fig.2). However, BA in WRH in the LG was significantly higher than that in the HG at channels 12 and 13 (*p <.1), and 16 (**p < .05) , representing an area approximately corresponding to Wernicke's area. In addition, BA during WRH in the LG was significantly higher than that in the HG at ch15 (*p <.1) and ch19 (**p < .05), representing an area approximately corresponding to Broca's area. These results suggest that linguistic areas, including rears resposible for vocaburary, were more activated in the LG in response to the target words when the participants did not answer correctly or took time to answer, whereas the same areas showed minimal activation in the HG because these participants knew the meaning of the target word, and quickly provided the correct meaning orally. Moreover, the BA at Chs10 and 18 in the LG was significantly higher than that in the HG (*p < .1), and these areas areapploxmetely correspond to the prefrontal cortex, which is relevant for WM. This result suggests that the participants in the LG used more WM to process the encoded information through Broca's and Wernick's area, other brain area playing roles in the processing of visual and auditory information, and areas participating in long-term and short-term memory functions.

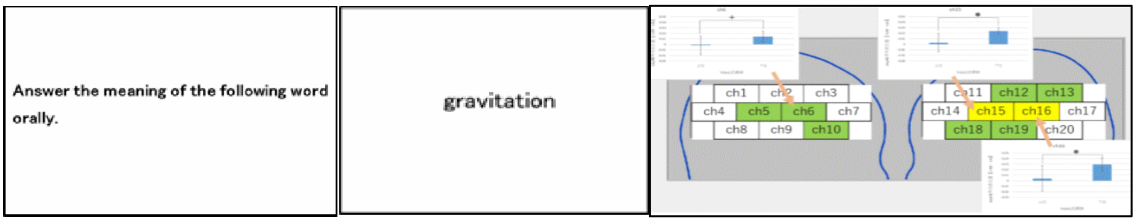

Fig.2 WRH task and the difference in BA between the HG and the LG according to each channel (HG<LG)

3.2 Listening and Oral (L and O) Task

Fig.3 shows that BA during the LU in the HG was significantly higher than that in the LG at Chs12,15, and 19, which partially correspond to Broca's area (** $p < .05$) and Chs 13 and 16, which partially correspond to Wernicke's area ($^{*}p < .1$). Because the participants were informed about the fowllowing activity, i.e., speaking the script for B and communicating with the script for A, in the final task before the target task, they might have focused more on listening to and comprehending the script of B, such that BA at Broca's and Wernicke's area in the HG was increased.

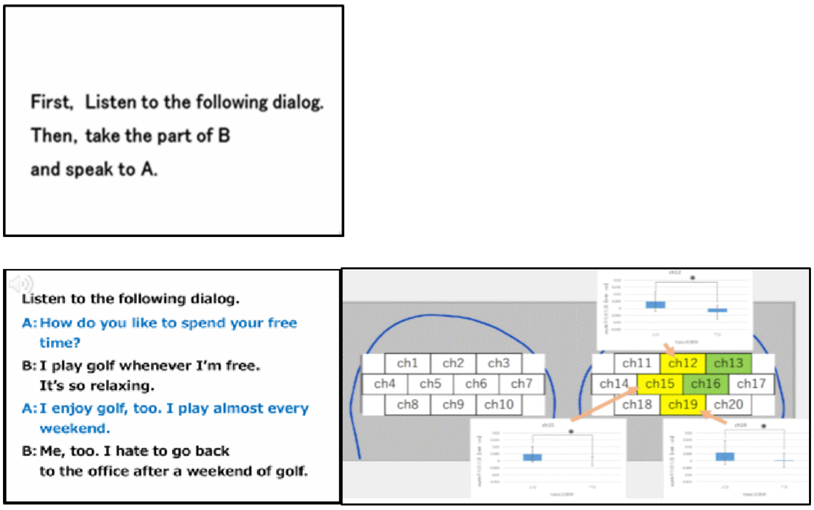

Fig.3 Task LU and difference in BA between HG and LG according to each channel (HG>LG)

However, in the OB task, as shown in Fig.4, BA in the LG was significantly higher than that for HG at Ch19 (*$p < .05$) and Ch 9 ($^{*}p <.1$), the part of which approximately conrrespond to Broca's area and the auditory association cortices, and at Ch12 and 16, which approximately correspond to Wernicke's area ($^{*}p <$ .1). Moreover, we found that BA in the LG at Ch18 (*$p <.05$) and Ch10 ($^{*}p<.1$) was significantly higher than that in the LG. These areas approximately correspond to the prefrontal cortex, which is relevant to WM. These results suggest that the participants in the LG used more WM while speaking to process the encoded information through Broca's and Wernick's area, brain areas playing roles in the processing of visual and auditory information and areas participating in long-term and short-term memory functions.

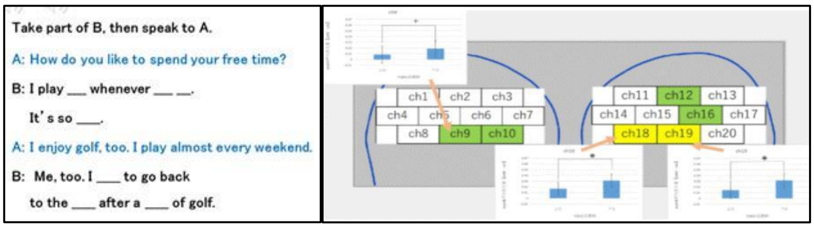

Fig.4 Task OB and the differences in BA between HG and LG according to each channel (HG<LG)

The data shown in Fig.5 reveal that BA in the HG at Ch 3 (*p < .05) and Chs 2, 6,13,and 20 ($^*p$ <.1) was significantly higher than that in the LG during the OU. Interestingly, Ch3 approximately corresponds to the prefrontal cortex, which is relevant for WM. These results suggest that the participants in the HG used more WM while speaking to process the encoded information through Broca's and Wernick's areas, brain area playing roles in the processing of visual and auditory information and areas participating in long-term and short-term memory functions. In the last task prior to the OU task, the participants focused on listening and memorizing to the blanked target words; thus BA was increaed in the participants in the HG compared with that in the participants in the LG because these particinats more actively used WM for long-term and short-term memory, auditory, and ligusitic functions.

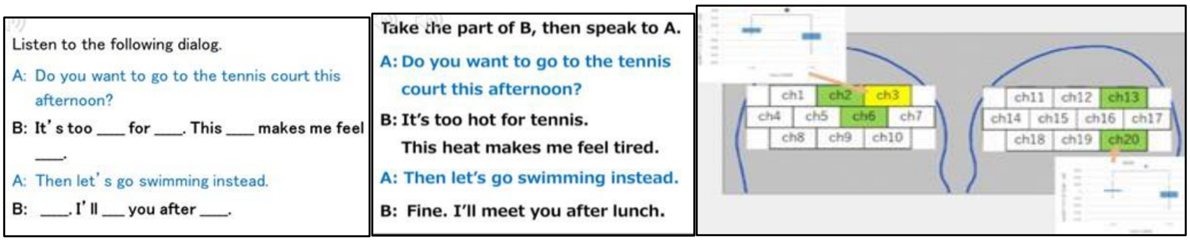

Fig.5 OU task after LB and difference in BA between HG and LG according to each channel (HG>LG)

3.3 Shadowing Task

The LShU of the shadowing task session is the final task before the ShU, and during this task, BA in the LG was significantly higher than that in the HG at Ch 12 (**p < .01), Chs 6, 9, 15, and 16 (*p < .05), and Ch17 ($^*p$ < .1), which approximately correspond to the Broca's and Wernick's areas and the auditory association cortices (Fig. 6). These results suggest that BA in the LG is highly activated while listening to the test contents and that the word level used during the target test may be relevant to BA in the participants. However, the word level might be irrelevant to BA in the HG.

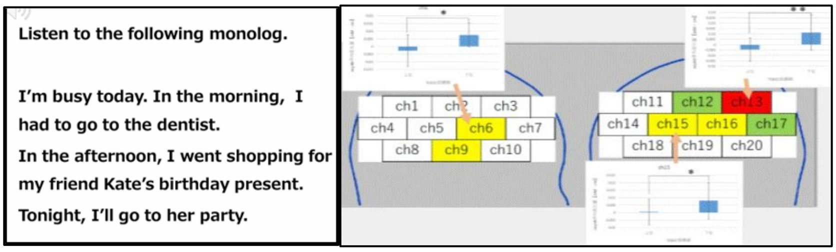

Fig. 6 LU task and difference in BA between the HG and the LG according to each channel (HG<LG)

BA in the HG during the ShU was significantly higher than that in the LG at Ch14 ($^*p$ < .1) (Fig.7) . Ch14 approximately corresponds to the prefrontal cortex, which is relevant to WM. While listening, the participants attempted to repeat, i.e., "shadow", what they heard as quickly as they heard it. These results suggest that the participants in the HG more actively used WM to process the encoded information through Broca's and Wernick's areas, brain areas playing roles in the processing of visual and auditory information and reas participating in long-term and short-term memory functions.

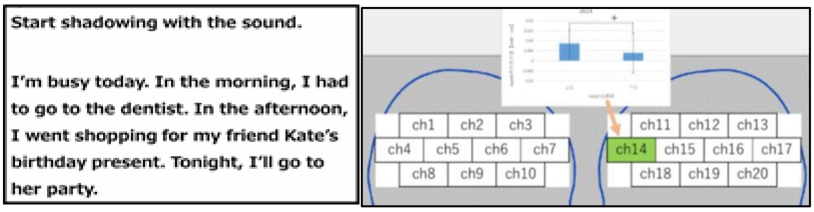

Fig.7 ShU task and the difference in BA between the HG and the LG according to each channel (HG>LG)

BA in the HG during the ShC was significantly higher that in the LG at Ch3 *(*p* < .05) (Fig.8) . Ch3 approximately correpond to the prefrontal cortex, which is relevant to WM. These results suggest that the participants in the HG more actively used WM while concentraiting on listening to the to the content of the closed script to process the encoded imformationencoded information through Broca's and Wernick's areas,brain areas playing roles in the processing if auditory information and areas participating in long-term and short-term memory functions.

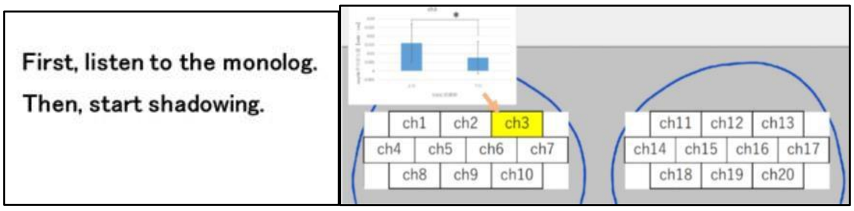

Fig.8 ShaC task and the difference in BA between the HG and LG according to each channel (HG>LG)

4. Conclusion

The present study revealed several findings that might suggest that SLA teaching/learning in the classroom make more effective from the data of BA experiment using fNIRS. Some suggestions for effective teaching and learning are as follows: choose an appropriate word level, focus on the target word or sentence by using spacing with blanks depending on individual proficiencies, and design the tasks depending on individual WM capacities.

Acknowledgement

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