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研究課題名（英文）Neural impact of native language literacy on the processing of non-native languages. Evidence from Chinese-English-Japanese and Vietnamese-English-Japanese trilinguals

研究代表者

ディン　ティ（Dinh, Thuy）

京都大学・医学研究科・研究員

研究者番号：３０６０２０７３

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研究成果の概要（和文）：1）fMRI撮影中は頭の動きがノイズの主因である。本研究は、fMRIデータのノイズ除去アプローチとしてはICA（独立成分解析）を実施した。全ICA成分の数は頭の平均運動値と各撮像のボリューム変位（FD）に強い相関関係が観察された。ICAが高運動関連のfMRIデータを検出する指標と考えられる。
2）本研究は、fMRIを用いて、中国語を母国語とし、外国語（L2）として日本語と英語を獲得した人を対象とし、外国語で音韻判断課題を求め、神経活動を計測した。日本語と英語の処理で異なる神経活動が観察された。この結果から、L2処理は、母国語の表記体系の特性を反映した異なる神経機構が作用していることが示唆された。

研究成果の学術的意義や社会的意義
While the native language (L1) is considered to be an inborn ability and acquired universally in the evolutionary process of human being, the nature of the second language (L2) is an acquired skill and the neural system involved in the operation of L2 may express the literacy influence of L1.

研究成果の概要（英文）：1)Head motion during the acquisition of fMRI data can significantly contaminate the neural signal and induce spurious, distance-dependent changes in signal correlations. Recently, ICA-based denoising technique has widely been used as a powerful tool for removing spurious motion-related signal from the data. The present study used ICA as a denoising approach and showed a strong correlation between the number of total ICA components with head mean motion and FD, which indicated that the number of ICA components can be a screening index for detecting high motion-related fMRI datasets.
2)The present study showed that there were different brain activation for phonological decision in Japanese and English languages in trilingual Chinese-native speakers. Once again, our results strongly demonstrated that nature of L1 literate influences how our brain processes the different L2 languages. This in turn may indicate that the educational strategies can be used to manipulate the acquisition of L2.

研究分野：linguistic fMRI

キーワード：bilingual　fMRI　language function

１．研究開始当初の背景

Movement of the head during scans causes undesirable temporal fluctuations (i.e., noise), which make the identification of the effects that are truly related to the underlying neural activities (i.e., signal) difficult.[1]. Especially, when we work in ultrahigh field MRI, the more signal we get, the more noise is accompanied. Therefore, denoising has become a crucial preprocessing step for fMRI data obtained at ultrahigh field such as 7TMRI. Recently, ICA (Independent Component Analysis)-based denoising technique has widely been used as a powerful tool for removing spurious motion-related signal from the data[2]. Furthermore, the framewise displacement (FD) variable, which measures movement of any given frame relative to the previous frame, has been used to regress out the head motion artifacts[3,4] and to standardize a cut-off threshold for excluding high motion-related fMRI datasets[5,6]. However, the relationship between FD and ICA analysis has not been much elucidated.

In the globalized era, speaking and understanding one or more non-native languages (L2) has been becoming an increasingly important skill. The acquisition of such literacy skills is essential for long-term success in academic and professional life and known to impact a broad range of human activity throughout lifespan[7,8]. It is unknown, however, how the brain learns a second language (L2) after the first language (L1) is acquired. Our previous work, by comparing brain activation between Chinese and Vietnamese participant groups who had learned Japanese as L2 while they are engaged in language comprehension and speech production tasks, has found different neural activities in the parietal temporal lobe of the left hemisphere in both tasks between the two populations. These results indicated that the linguistic background of L1, which has been shown as an important factor in selecting reading strategy of L2, also influences the understanding and speech expression of L2. The limitation of our previous data is that we could not compare the direct language distance between two different L2 systems intra subjects. Therefore, the present project aimed to do that by examining a group of trilingual participants.
Our initial plan was to perform this project on 3T-MRI device of Human Brain Research Center at Kyoto University. However, because the closure of the 3T-MRI device, we had to move our plan to the new 7 Tesla (7T)-MRI device. Therefore, we had to perform a setting-up experiment (**Experiment 1**) for checking the quality of fMRI data at 7T-MRI first and then performed the main linguistic experiment (**Experiment 2**).

２．研究の目的

Experiment 1 aimed to investigate the influence of head motion on the output of ICA-based denoising, then to clarify whether we can use ICA results to qualify fMRI datasets.
By examining a group of trilingual participants, Experiment 2 aimed to clarify the impact of language distance between L1 and L2 on the processing of L2.

３．研究の方法

Experiment 1: 24 right-handed young healthy subjects (aged 20 - 25 years) participated in the study. Block-designed fMRI was used. In each fMRI run lasted for 6min30sec, the subjects performed left hand grip motor task at 1Hz frequency during task blocks. MRI scans were performed with a 7T whole-body scanner (MAGNETOM 7T, Siemens Healthineers). For functional volumes TR/TE = 1000/22 ms; FA = 45°; MB =5, GRAPPA = 2, spatial resolution = isotropic 1.6 mm; for anatomical images a whole-brain MP2RAGE with TR/TE/TI1/TI2 = 6000/2.9/800/2700 ms; FA1/FA2 = 4/5°, spatial resolution = isotropic 0.7 mm) were acquired. The fMRI dataset was preprocessed by using a default preprocessing pipeline of HCP pipeline protocol. The mean motion of an fMRI run and FD were quantified[4]. Motion related fluctuation and different sources of artifacts were removed from the images using FMRIB's ICA-based X-noiseifier (FIX) denoising analysis[9].

<u>Experiment 2:</u> Participants were 15 late trilingual subjects (aged 21 - 30 years) who were Chinese native speakers and highly proficient learners with different writing systems for their non-native languages (L2), one morphemic (Japanese) and the other phonetic (English). High proficiency of L2 was proven by certification of the Japanese Language Proficiency Test (JLPT) and English Proficiency Test (TOEIC, TOEFL, IELTS). A questionnaire confirmed that no one started learning L2 before the age of 12 (i.e., late L2 learners).

All participants performed the sequentially phonological categorization task inside the fMRI scanner. The participants were asked to decide whether the sound (phonology) of presented picture had the same initial letter with its previously presented stimulus (Figure 1) and gave their answers by pressing the buttons. In each fMRI run, participants performed the task in an indicated language following the instruction.

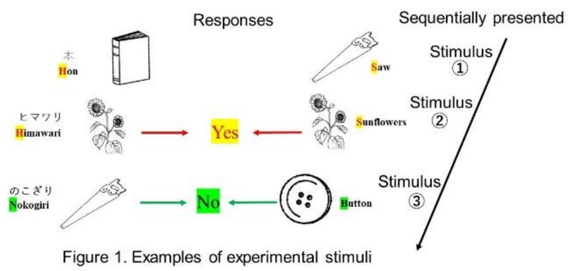

Figure 1. Examples of experimental stimuli

Event-related design was used. Each MRI run consisted of 150 trials, including 120 task trials presented in a random order, intermixed with 30 baseline trials, lasting about 10 minutes in lengths (600 volumes of 1s each). Each subject participated in 6 runs of 3 languages (2 runs for each language). MRI data of functional volumes and anatomical images were acquired with the same scan parameter described in Experiment 1. fMRI data was analyzed using SPM12.

４．研究成果

Experimental Results:

<u>Experiment 1:</u>

For each fMRI run, the average number of total ICA components was 116.2 (SD = 29) and the average numbers of signal/noise/unknown components were 37.8/62.6/15.8 (32.5/53.9/13.6 %), respectively. These results were re-confirmed by manual labelling, which showed that variance was less than 10% for each component classification (data are not shown). The total number of ICA components showed a strong correlation with mean motion (Figure 2) and FD (Figure 3).

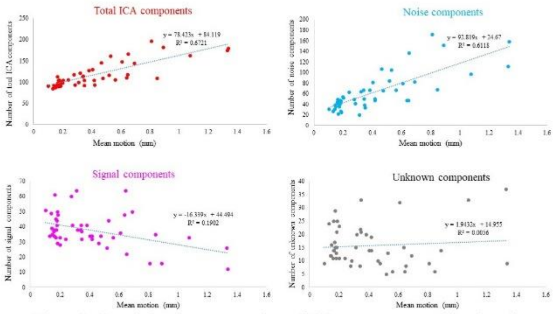

Figure 2. Correlation between number of ICA components and head motion

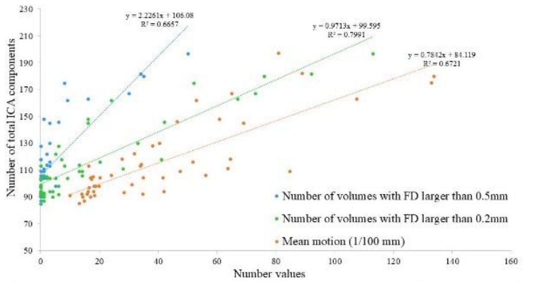

Figure 3. Correlation between number of ICA components with FD and head motion

Experiment 2:

In comparison with native language (i.e., Chinese) condition, both non-native language (i.e., Japanese and English) conditions showed a common stronger action in the left inferior frontal in both superior occipital lobes. Despite having no significant differences in behavioral performance between the Japanese and English languages conditions, the Japanese condition showed significantly higher activity in in the left anterior superior temporal lobe while the English condition showed greater activation in the left parietal lobe (Figure 4).

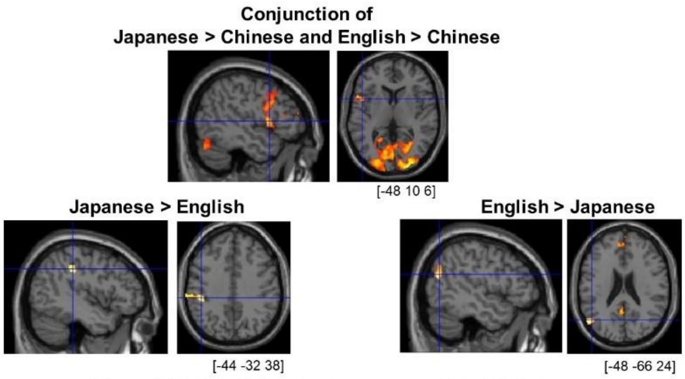

Figure 4. Brain activities for Japanese and English languages

Discussion and Conclusion:

The acquisition of BOLD signal depends on precise spatial and temporal placement of magnetic gradients. Movement of the head during scans not only shifts the position of the brain in space but also disrupts the establishment of temporal readout of the BOLD signal[1,10] resulting in spurious motion-related signal in the data. Therefore, evaluating and correcting head motion of an fMRI dataset is crucial. The fact that the number of total ICA components has a strong correlation with both mean motion and FD variables suggested that ICA decomposition can detect the spatial changes of the head throughout the fMRI scan, and the output results (i.e., the number of ICA components) indicated how much the subject moved during the scan. Therefore, the number of total ICA components from ICA-based denoising analysis can also be used as an qualified index for evaluating and detecting high motion-related fMRI datasets.

Because previous studies have identified several major determinants for the difference in brain activation of L2, such as age of L2 acquisition[11], L2 proficiency level[12], we controlled for these factors in the present study.

The role of the inferior frontal junction in retrieving our memories to facilitate for detection of targeted objects[13]. The fact that the processing of both L2 (i.e., Japanese and English) produced a higher brain activity in this area than L1 (i.e., Chinese) reflected a higher demand of attention for performing the task in L2.

With controlling factors known as major determinants for the difference in brain activation of L2, the observed difference in brain activation patterns between Japanese and English processing should be attributed to the linguistic distance between L1 and L2. i.e., between morphologic (Chinese)-morphologic (Japanese) and morphologic (Chinese)-phonemic (English). While Chinese participants are likely to rely more on visuo-orthography transformation in English task, they need to enhance the phonological retrieval process for performing the task in Japanese.

In conclusion, it is well-known that the native spoken languages (L1), which are acquired during the evolutionary process, are universal abilities of our human being[14]. However, unlike the L1, which is considered as an innate ability, the expression of non-native languages (L2) are influenced by the literacy of L1, and/or the different distance between L1 and L2, as shown in the present study. This indicates that the nature of L2 is a kind of acquired skill of our human being[15].

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５．主な発表論文等

〔雑誌論文〕　計0件

〔学会発表〕　計1件（うち招待講演　0件／うち国際学会　1件）

１．発表者名 Dinh Ha Duy Thuy
２．発表標題 Influence of head motion on the output of Independent Component Analysis (ICA)-based denoising of task-related fMRI data at 7T
３．学会等名 ISMRM2021（国際学会）
４．発表年 2021年

〔図書〕　計0件

〔産業財産権〕

〔その他〕

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６．研究組織

	氏名 （ローマ字氏名） （研究者番号）	所属研究機関・部局・職 （機関番号）	備考
研究分担者	中村　仁洋 (Nakamura Kimihiro) (40359633)	国立障害者リハビリテーションセンター（研究所）・研究所脳機能系障害研究部・主任研究官 (82404)	
研究分担者	藤本　晃司 (Fujimoto Koji) (10580110)	京都大学・医学研究科・特定准教授 (14301)	
研究分担者	岡田　知久 (Okada Tomohisa) (30321607)	京都大学・医学研究科・准教授 (14301)	

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