1)
IRB   , 2)   fNIRS
                                        3)
fNIRS   , 4) 20   fNIRS
                L2
                                                , 5)   3   .

- I can now provide other KU researchers in non-technical fields guidance in doing clinical research on our campus.
- The gathered data may provide insight into the mechanisms of L2 acquisition.
- I have established inter-departmental cooperation with KU Hospital for future related research.

In the present research period, I have accomplished the following: 1) Created a liaison between our Faculty of Languages and Cultures and Kyushu University Hospital and established a precedent/template in which the latter provides IRB certification for "clinical research" in our department, 2) Purchased a portable functional near-infrared spectroscopy (fNIRS) device, now available here on our Ito Campus for future research in the PI's laboratory as well as in collaborations with other researchers interested in fields such as neurolinguistics, 3) Established a reproducible, reliable protocol for collecting fNIRS data in healthy Japanese subjects in a non-clinical setting such as on our campus, 4) Collected fNIRS and behavioral data in 20 subjects to corroborate the controversial bilingual advantage hypothesis by correlating L2 (English) proficiency with changes in prefrontal oxygenated hemoglobin (data analysis pending), 5) Published three research articles in related fields

Neurolinguistics

fNIRS bilingual advantage EVT FAS test L2 acquisition

Bilinguals are thought to have certain cognitive advantages over monolinguals, and they have been reported to outperform monolinguals on non-verbal tasks such as those requiring conflict resolution and task-switching. This "bilingual advantage" may originate from continuous practice controlling attention to two different language systems, resulting in a more efficient executive control system. (e.g. Kroll & Bialystok, 2013, *J Cogn Psychol 25*:497-514).

In addition to non-linguistic cognitive control tasks, executive control is also considered an important component of certain verbal fluency tasks. Indeed, executive control functions such as conflict monitoring and working memory have been connected to the accomplishment of phonemic fluency tasks (PFT) (e.g., Hurks, 2012, *Clin Neuropsych 26*(6): 1019-1037). Furthermore, performance advantages in PFTs by highly- proficient bilinguals over low-proficiency bilinguals have been reported (e.g., Luo et al., 2010, *Cognition 114*(1): 29-41) and interpreted as a reflection of enhanced executive control ability.

In our previous study (Wroblewski et al., 2017, *NeuroReport 28(14*): 884-889 ‒ using functional near-infrared spectroscopy (fNIRS), a limited sample of Japanese university students in a HIGH English proficiency group completed PFTs in both Japanese and English with almost no significant activity in frontal, parietal, and temporal cortex regions while those in the LOW group demonstrated widespread activity. Because there is overlap between areas activated during PFTs and those of non-linguistic executive control tasks (e.g., De Baene et al. 2015, *J Cog Neuro 27*(9): 1752-1765), our results hinted at a bilingual advantage in executive functioning.

However, the question still remains: Can neuroimaging evidence for the purported bilingual advantage observed in behavioral studies be clearly documented using neuroimaging? To achieve this, the current research set out to use a fNIRS system in conjunction with a verbal fluency task (FAS test) on healthy young Japanese university students, who have been carefully ranked by a standardized measure of English proficiency, the Pearson Expressive Vocabulary Test.

Purpose: To explore the effects of second language (L2) proficiency on frontal brain activity of healthy young Japanese during a verbal fluency task to determine the existence of a bilingual advantage in executive function, answering the following questions specifically:

A) Can differences in L2 proficiency be observed in the frontal brain regions using neuroimaging?
Although behavioral tasks have suggested a bilingual advantage in verbal fluency, these have yet to be clearly supported through neuroimaging. To answer this question, we set outto   a verbal fluency task under fNIRS in Japanese university students of varying English proficiency to observe changes in brain activity in the frontal cortical brain regions.

(B) Do activation patterns persist when analyzed according to finely-graded L2 proficiency tests?
Although we have previously shown that a stark difference in the number of brain activations exists during PFTs when dividing subjects into HIGH and LOW TOEIC groups, it is unclear whether this trend will persist when data is analyzed according to more finely-graded language proficiency measures. Likewise, previous measures of English proficiency such as the TOEIC may not have reflected the most up-to-date and accurate L2 proficiency of participants. For this reason, we set out to use expressive vocabulary tests *just prior* to fNIRS measurement to increase the granularity and timeliness of the English proficiency measurement.

(C) Are differences in frontal activation pattern trends limited to the highly-proficient?
Although our previous study showed differences in frontal activation patterns between HIGH and LOW groups, the minimum TOEIC score was 600 (all medical students). In the present

study, we set out to recruit participants from various faculties in order to ensure a broader range of English language proficiencies being represented, and will continue to encourage participants from other faculties as well.

(D) Do activity patterns for bilinguals differ by language of administration? Phonemic fluency task performance is thought to be partially language-dependent (e.g., Sumiyoshi et al., 2014, Schizo Res 152(2-3): 421-429). For these reasons, we set out to administer the test to each participant in both English *and* Japanese for comparison's sake.

(A) Demographic data collection

Undergraduate Kyushu University students were recruited from the PI's English courses through an advertisement. Upon arrival at the research lab, informed consent was obtained from each student after a Japanese language explanation of the experiment. Demographic data was then collected, and participants were also assessed for handedness.

(B) English proficiency assessment

English proficiency was assessed through the Pearson Expressive Vocabulary Test (EVT-3), a standardized vocabulary test administered via iPad, in a process taking about 15 minutes.

(C) Activation task and fNIRS data collection

For each participant, relative changes in oxygenated hemoglobin were measured during two separate PFTs – one in Japanese and one in English, using the Spectratech OEG-16 fNIRS system. Preliminary instructions were provided in Japanese (written) and English (verbal). Each task included a 30-s pre-task baseline period, a 60-s word production period comprising three 20-s blocks, and a 70-s post-task baseline period. During the baseline periods, participants were asked to vocalize either the five Japanese or five English vowels in order and repeatedly. During the word production period, participants were asked to produce as many words as possible for a given Japanese mora/English letter.

(D) Data analysis

Statistical analysis – pending – will be outsourced to B.R. Systems Inc. (Kanagawa, Japan), who specialize at analysis of data obtained by OEG-16.

Due to the influence of the COVID-19 pandemic, the initiation of data collection and the recruiting of participants was much, much slower than originally expected when the original research plan was written. Likewise, obtaining a fNIRS device was affected by supply chain issues in wake of the worldwide effects of the pandemic. Although institutional COVID-19 restrictions were eventually relaxed, potential participants (students) seemed reluctant to be an enclosed space for upwards of an hour for data collection in a small office. Also, it appears that the "salary" stipulated by Kyushu University (¥1000 QUO card) for 60 minutes' work may not have been enticing enough to cause busy students to volunteer. Finally, in light of my other job responsibilities, including 8 koma per week, I was only able to devote one day per week to research, and the available day did not always lend itself student availability.

For this reason, data was only collected from 20 participants, with data analysis still pending. Nevertheless, the current research project has born fruit in several areas:

- A liaison between our Faculty of Languages and Cultures and Kyushu University Hospital was established and a precedent/template in which the latter provides IRB certification for "clinical research" in our department was also created.
- Our research lab purchased a portable functional near-infrared spectroscopy (fNIRS) device, now available here on our Ito Campus for future research in the PI's laboratory as well as in collaborations with other researchers interested in fields such as neurolinguistics
- We established a reproducible, reliable protocol for collecting fNIRS data in healthy Japanese subjects in a non-clinical setting such as on our campus
- Collected fNIRS and behavioral data in 20 subjects to corroborate the controversial bilingual advantage hypothesis by correlating L2 (English) proficiency with changes in prefrontal oxygenated hemoglobin (data analysis pending)
- Three research articles in related fields were published.
- We can now provide other KU researchers in non-technical fields guidance in doing clinical research on our campus.

The data collected will be analyzed shortly, hopefully leading to insights into the neural correlates of L2 proficiency.

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