Bilingual First Language Attrition from Linguistic and Neuroimaging Perspectives: A functional near-infrared spectroscopy (fNIRS) study

Hideyuki Taura* and Miho Nakanan**

Abstract

This study attempts to examine if functional near-infrared spectroscopy (fNIRS) can detect the phenomenon of bilingual language attrition to an equal or superior degree to conventional linguistic approaches. For this purpose a combination of a writing task and verbal fluency task (VFT) were used to collect linguistic and neuroimaging data respectively, from an early Japanese-English bilingual over a period of three years. Special focus was placed on the effect of her drastically reduced English after her return to Japan. The linguistic examination included writing skills, accuracy, fluency, and lexical analyses based on collected writing samples while neuroimaging analyses were conducted on oxygenated hemoglobin signals obtained during the VFT. The results revealed quite contrasted findings - the linguistic approach detected little attrition other than a slight lexical density decline, whereas the neuroimaging analyses in Broca's area indicated that English attrition was evident in the second year and the participant's dominance of English had disappeared in the third year on the letter task.

Keywords: attrition, BFLA (bilingual first language acquisition), fNIRS (functional near-infrared spectroscopy)

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1. Introduction

1.1 Neurolinguistic research on bilingual attrition

Enquiry into the mechanism of bilingual language processing on how two languages are networked in the brain has attracted a number of researchers. Ameel *et al.* (2009), for instance, looked into how semantic convergence is manifested in the bilingual mental lexicon, using a conventional psycholinguistic method of labeling pictures. As a branch of bilingual research, non-pathological language attrition has been explored over the past few decades as a phenomenon of a decline or loss of ability or competence in one of the two languages bilinguals possess once they are removed from a particular language environment (e.g. Francis, 2011; Guel, 2004; Kopke, 2004; Pradis, 2008; Scherag, 2004; Schmid *et al.*, 2004; Taura, 2008).

With the recent advance of brain-imaging technology, linguists such as Rossi *et al.* (2012) had taken a neurolinguistic approach to identifying where the language processes are taking place in the brain. Green and Abutalebi (2008) and Marsh *et al.* (2008) share similar opinions in stating that the brain-imaging technique promises a better understanding of language development in the brain. Bilingual language acquisition has also been explored under the neurolinguistic discipline umbrella. Moreno *et al.* (2008) reviewed a large body of event-related potentials (ERP) research covering from bilingual phonological, lexico-semantic, and morphosyntactic processes to code-switching, then they suggested the potential direction ERP research should take to clarify the issues unsolved by bilingualism researchers. A functional near-infrared spectroscopy (fNIRS, henceforth) has also been used in this line of inquiry. Oi *et al.*, (2010), for instance, examined Chinese-Japanese bilinguals and found that bilinguals suppress semantic information in the left dorsolateral prefrontal cortex whereas the right homologous area directs attention to the target language. Petitto *et al.* (2012), conducting an fNIRS experiment, put forward the 'Perceptual Wedge Hypothesis' to explain how bilingual experiences alter neural and language processing in an advantageous way for bilinguals. It is true that there have been some clinical studies that looked at bilingual aphasic patients, using neuroimaging techniques (e.g., Ansaldo *et al.*, 2008). However, to the best of our knowledge, no non-pathological attrition studies have taken a neuroimaging approach on bilinguals to date.

1.2 fNIRS use in language studies

Among the variety of brain imaging techniques, the non-invasive functional neuroimaging method known as fNIRS has proved to be easier to use and sensitive to detecting small substance concentrations, with a high temporal resolution (Toga and Mazziotta, 2002). In principle, fNIRS measures brain activation using changes in the intensity of light detected by source and detector probes that are attached to the head with a harmless light that penetrates the brain. Other brain imaging techniques including fMRI (functional magnetic resonance imaging), PET (positron emission tomography), and MEG (magnetoencephalography) require large and bulky instruments which make it difficult for small children to be examined. In comparison, fNIRS uses light via fibre optics, which can even allow babies to be examined (Miyai *et al.*, 2001). In addition, fNIRS is sensitive to a very low substance concentration using a fluorescence method and the result is similar to a PET scan without the disadvantage of radioactive tracers. Temporal and spatial resolution differ vastly from one brain imaging method to another: high temporal resolution is obtained using the MEG eletrophysiological method (starting from 1 millisecond) while hemodynamics-based techniques such as fMRI (starting from 1 millimeter) provide a greater spatial resolution. fNIRS offers a smaller, easier-to-use option to monitor vascular, metabolic-cellular, and neuronal responses with a high temporal resolution of about 1,000 milliseconds, despite a low spatial resolution of about 3 cm. It is also recognized that fNIRS data are consistent with the fMRI Blood Oxygenation Level Dependent signals to predict hemispheric dominance on linguistic tasks (e.g., Kennan *et al.*, 2002).

fNIRS has been widely used and proved to be useful in various academic disciplines (see Ansaldo *et al.*, 2012 for summary). In the field of linguistics, fNIRS is superior to other functional neuroimaging techniques from the participants' point of view in that it allows them to be seated in front of a computer screen without being placed in a closed-in noisy tube-like machine as they do in an fMIR experiment, when they engage in a language task (for overview see Gallagher *et al.*, 2012 and Quaresima *et al.*, 2012), particularly in children (e.g., newborns to adults in Quaresima *et al.*, 2012; pre-school children in Hidaka *et al.*, 2012; elementary school children in Sugiura *et al.*, 2011). Such neuroimaging researchers as Ameel *et al.* (2009), Midgeley *et al.* (2009), Rossi *et al.* (2012), Sugiura *et al.* (2011) successfully examined the first and second language network in the brain, which makes it a hopeful method for fNIRS researchers to identify how early bilinguals' languages are processed.

In addition to monolingual language processing (e.g. Tupak *et al.*, 2010; Quaresima *et al.*, 2000), a number of fNIRS studies have examined bilingual language processing (e.g., Kovelman *et al.*, 2009; Midgeley *et al.*, 2009; Oi *et al.*, 2010; Quaresima *et al.*, 2010; Schrerer *et al.*, 2012) using a verbal fluency task (VFT, henceforth) and found it to be a useful tool. fNIRS studies using VFT also found that oxygenated hemoglobin (oxy-Hb) signals detected an fNIRS increase in brain activation throughout a period of language stimulation and a subsiding at the end of the task (Quaresima *et al.*, 2012). In addition, a more advanced level of language meant that the speaker required less of an effort to produce it and thus the language processing became more automatic, resulting in a decreased oxy-Hb level (Saidi *et al.*, 2013).

fNIRS has also been widely used in clinical settings to detect the language faculty (see Klumpp and Deldin, 2010 for overview) or how languages are processed, especially how words are retrieved, in the healthy ageing population by researchers such as Heinzel *et al.* (2013) and Kahlaoui *et al.* (2012). The present enquiry into bilingual first language attrition in young bilinguals is therefore a valid attempt to use a VFT and fNIRS equipment.

Abutalebi *et al.* (2009), after reviewing recent neuroimaging studies on bilinguals, suggested three future directions which include (1) longitudinal studies to investigate the natural course of language acquisition, (2) studies that focus on exposure rather than proficiency, and (3) cross-linguistic studies comparing linguistically distant languages. In line with these suggestions, the present fNIRS study is a longitudinal case study examining how language attrition occurs once language exposure is significantly reduced in an early bilingual whose languages, alphabetical (English) and logographic (Japanese), are linguistically distant.

1.3 Research question

The literature review above led us to formulate the following research question:

2. Method

2.1 Participants

The one female participant in this study was born and raised in the USA and attended local American school until 2010 when she turned 16;02, finished G9 and returned to Japan where for the first time in her life she attended a Japanese school as a G10 student. During her stay in America, her school language was entirely English which was also the sibling language between herself and her sister although her Japanese parents insisted on their addressing to them in Japanese at home. They kept initially English as their communication language back in Japan with occasional code-switching into Japanese. This language choice, however, had reversed by 2012 when they mostly used Japanese between them except for occasional code-switching into English.

In the fourth month after her return to Japan in October 2010 (INC 0.04 years), the first data were collected. When the second and third data were collected, she was 17;06 (INC 1.04 years) and 18;05 (INC 2.03 years), respectively. The Japanese school she goes to is unique in that it shares the same school site with an international school to create an ideal environment for Japanese returnees to maintain their hard-won English. Being placed in the highest level English class at her own Japanese school, she joins in the mainstream (IB) English class at the international school while other academic subjects are all taught in Japanese at the Japanese school, using textbooks screened by the Japanese Ministry of Education.

Each year this participant self-assessed her Japanese and English proficiency in the four skills of reading, writing, listening, and speaking in comparison with NS with 1 being definitely inferior to NS, 3 equal to NS, and 5 definitely superior to NS. She was also asked about her strongest language at the yearly experiments. These results are summarized in Table 1.

Table 1. Language self-assessment

	Strongest	Japanese				English			
Year	Language	Reading	Writing	Listening	Speaking	Reading	Writing	Listening	Speaking
2010	English	2	2	3	3	3	3	3	3
2011	English	2	2	3	3	2	4	3	2
2012	English	3	3	3	3	3	5	5	3

Since she has been exposed to authentic Japanese and English on an everyday basis at school, it is presumed that she is capable of validly self-evaluating her language proficiency. Upon return to Japan, she judged her English proficiency equivalent to her counterparts in the USA in all of the four skills while she evaluated her Japanese oral skills (speaking and listening) equal but literary skills (reading and writing) inferior to her counterparts in Japan. In 2012, two years later, she found that she had caught up in her Japanese literary skills equivalent to her Japanese classmates. In English, she found her writing and listening skills improving all the time in Japan to reach a higher self-evaluated level than her English native-speaker friends. A post-hoc interview in 2013 revealed that she had struggled in 2010 to catch up in Japanese since high school textbooks are full of new and difficult concepts and terms, although by the end of the first year she had found herself not needing to make as much effort in Japanese as before. Thus, her own judgement on her Japanese skills changed in a favourable manner from the second year.

Taking De Houwer's strict definition on bilingual first language acquisition (2009; 98) of (1) no time lag between the baby's first hearing of Language A and Language B and (2) constant and regular exposure to the two languages, we judged the participant in this study as an early simultaneous Japanese-English bilingual and decided to observe English out the of her two first languages since her language environment changed from English to Japanese.

2.2 Tasks & data analysis

A writing test and a verbal fluency task are used in this study in an attempt to observe bilingual first language attrition and retention from both linguistic and neuroimaging perspectives.

2.2.1 Writing task

To examine the participant's linguistic skills, written data in English were collected once a year over a three-year period using the Test of Written Language (TOWL-3) by Hammill and Larsen (1996). The test simply asks the participant to look at a prehistoric or futuristic picture, and create and write a story about it in 15 minutes. It employs analytical and holistic measurements to examine three aspects of writing: (1) Conventional Component (CC) such as punctuation, capitalization, and spelling, (2) Contextual Language (CL) such as syntactic, morphological, and semantic elements, and (3) Story Construction (StC) such as logical and coherent story development and reader impact. TOWL-3 also calculates an overall writing score by adding the three-subset scores and converting the sum into a Quotient. Each writing sample was scored according to the scoring manual provided by TOWL-3 to first produce raw scores for CC, CL, and StC and then to convert them into age-appropriate standard scores with 8-12 points indicating the native speaker average, which is set between 90 and 110 points in the overall writing scores of the Quotient.

In addition to these TOWL-related scores, the writing samples underwent lexical, accuracy and fluency analysis. The lexical analysis was carried out in terms of the number of different words (types) and the total number of words (tokens) as well as the lexical density (TTR - type token ratio), using a software program *the Complete Lexical Tutor* (http://www.lextutor.ca/). The morphosyntactic accuracy analysis was based on Myers-Scotton's 4-M model (2002). Fluency was measured with the number of morphemes, types (different words), and sentences produced per minute.

2.2.2 Verbal fluency task

To obtain fNIRS data from our participant, a linguistic task called a verbal fluency task (VFT) was administered each year. The VFT included four sub-tasks: two Japanese and English letter tasks and two Japanese and English category tasks. The blocked design with time durations for each year is shown in Figure 1.

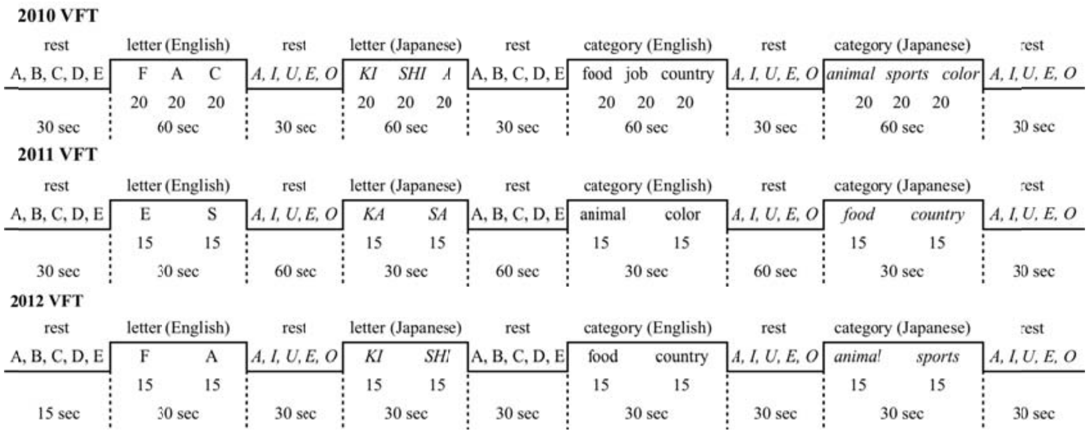


Figure 1. Blocked design for VFT in 2010, 2011, and 2012 and prompt letters and words

The English letter task 'A', for instance, meant that the participant had to produce as many words as possible beginning with the prompt letter ‘A’ such as 'apple' and 'acorn' while the category task of 'animals' was that she had to say as many names as possible such as 'dogs' and 'cats'. The selection of the prompt letters and categories for the present study was based on such previous research as Schecklmann *et al.* (2008) and Ehlis *et al.* (2007) for the English tasks and Arai *et al.* (2006), Kameyama *et al.* (2004), and Murai *et al.* (2004) for the Japanese tasks.

The blocked design, rather than event-related method, was judged better suited to this study in that precise activation data are obtainable by subtracting the preceding rest task (as an arbitrary unit of mMmm) from the data of the individual verbal fluency tasks. When a person reads a letter or word on a computer monitor and says it aloud, the area of the brain that is activated first is the primary visual cortex, followed by Brodmann's areas numbered 19, 39, 37, and 42, then Wernicke's area, and finally Broca's area. When a person performs a VFT, the brain undergoes the identical activation as just mentioned, when accessing the mental lexicon and retrieving the words prompted by the cue letters or words. Thus, the subtraction of the fNIRS data taken during the rest task from the VFT fNIRS data can be verified as representing the lexical access and retrieval in a particular verbal fluency task.

As an example, in 2010 (Figure 2) our participant began the VFT by saying aloud 'A, B, C, D, E' repeatedly for 30 seconds as a rest task then upon a signal began the English letter task where she had to say aloud as many words as possible starting with 'F' for the first 20 seconds, 'A' words for the next 20 seconds, and 'C' words for the last 20 seconds. The prompt letters and words in the VFT were similar across the three years as can be seen in Figure 2. Meanwhile, the time duration varied from 30 seconds in the first rest task in 2010 to 15 seconds in 2012 while the English letter task lasted for 60 seconds in 2010 but only 30 seconds in 2011 and 2012. In order to make a yearly comparison possible, it was decided to use the last 15 seconds of fNIRS data in the rest tasks and to use the first 15 seconds of fNIRS data for each verbal fluency task in 2011 and 2012. However, in 2010 each VFT lasted for 60 seconds, which was double the length of time in the other two years, therefore the data showing the most brain activity during 15 seconds were visually identified by referring to the trend graph provided by the fNIRS machine (Figure 3) for both VFT tasks and rests, and they were subtracted in the same way as 2011 and 2012.

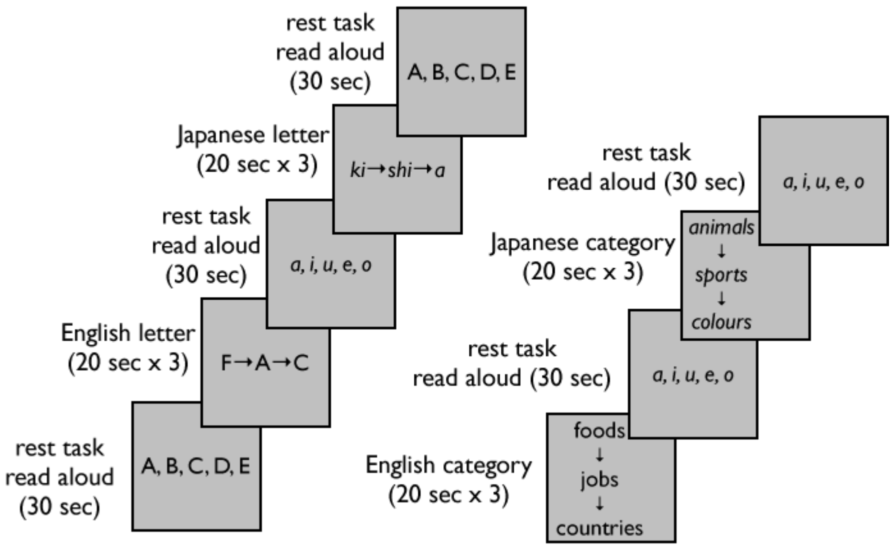


Figure 2. VFT slides on the PC screen in 2010 (letter tasks on the left and category tasks on the right)

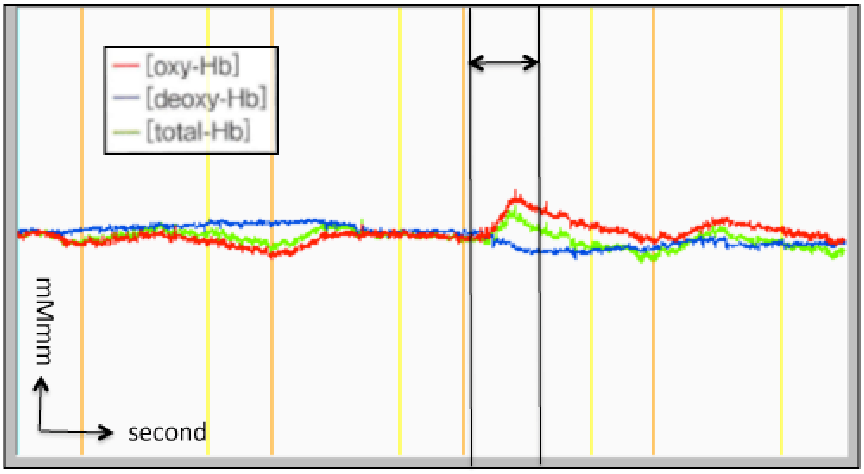


Figure 3. Trend graph showing15 seconds identified with the most activation

The actual subtraction proceeded in the following manner. The fNIRS data taken from the channels identified as Broca's area (channels 17, 25, and 34 in Table 2) and its homologous area in the right brain were converted into z-scores, which is a first step to make the data comparable among samples derived from other tasks and years. Then, the z-scores were divided into the five rest tasks and four VFTs, judged by the time indices. Thirdly, the z-scores of three channels identified as Broca's area were averaged out. Lastly, from the z-scores of certain VFTs, those of the rest task preceding the task were subtracted. In so doing, the fNIRS data identified as the values taken from the most activated 15-second in each task and rest were used. For instance, the bold z-scores in the middle row labeled as oxy-Hb in the first rest task in Table 3 were subtracted from the bold z-scores in the far right row labeled as oxy-Hb in the English letter task. The same procedure was repeated for all the tasks in each year. The subtracted z-scores were the fNIRS data used for the statistical analyses.

Table 2. Examples of fNRS raw scores in Broca's area (left) and their z-scores (right)

Time(sec)	ch-17 oxyHb	ch-25 oxyHb	ch-34 oxyHb	Time(sec)	ch-17 oxyHb	ch-25 oxyHb	ch-34 oxyHb
0	0	0	0	0	-0.663240013	0.260681015	0.23114553
0.13	0.011344	-0.002009	0.000586	0.13	-0.036020973	0.188197325	0.255885474
0.26	0.004413	-0.014085	-0.006937	0.26	-0.419241633	-0.247498566	-0.061723049
0.39	-0.004333	-0.012881	-0.0138	0.39	-0.902815127	-0.204058863	-0.351467471
0.52	0.001216	-0.007986	-0.005589	0.52	-0.596006378	-0.027449772	-0.004812735
0.65	0.026323	-0.013102	-0.015813	0.65	0.792180189	-0.212032429	-0.436452976
0.78	-0.014617	-0.011248	-0.015886	0.78	-1.471425899	-0.14514106	-0.439534915
0.91	-0.023567	-0.020701	-0.014068	0.91	-1.96627872	-0.486200454	-0.362781985
1.04	-0.00413	-0.009603	-0.010069	1.04	-0.891591091	-0.085790303	-0.193950869
1.17	0.009241	-0.007194	-0.005297	1.17	-0.152297564	0.001125182	0.007515018
1.3	-0.004045	-0.011603	-0.007364	1.3	-0.886891371	-0.157949278	-0.079750277
1.43	-0.006188	-0.00467	-0.00456	1.43	-1.005379594	0.092189809	0.03862993
1.56	0.006896	-0.014902	-0.012554	1.56	-0.281954532	-0.276975507	-0.298863428
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–
30.03	-0.002165	-0.024994	-0.032122	30.03	-0.782944634	-0.641089694	-1.124991777
30.16	0.001356	-0.042944	-0.034617	30.16	-0.588265663	-1.288716494	-1.230326518
30.29	-0.008967	-0.018412	-0.024404	30.29	-1.159032778	-0.403614508	-0.799150679
30.42	0.000916	-0.017887	-0.023822	30.42	-0.612593623	-0.384672777	-0.774579609
30.55	-0.016483	-0.022826	-0.026929	30.55	-1.574598566	-0.562869365	-0.905751971
30.68	-0.012043	-0.024671	-0.02833	30.68	-1.329107334	-0.62943602	-0.964899856
30.81	-0.017631	-0.025916	-0.034395	30.81	-1.638072425	-0.674354981	-1.220954048
30.94	-0.012206	-0.03563	-0.033729	30.94	-1.338119737	-1.024831123	-1.192836638
31.07	0.007393	-0.027184	-0.023767	31.07	-0.254474995	-0.720103772	-0.772257601
31.2	-0.006264	-0.027765	-0.025787	31.2	-1.009581697	-0.741065954	-0.857538634
31.33	-0.008557	-0.025142	-0.022727	31.33	-1.136363542	-0.646429458	-0.728350534
31.46	0.005373	-0.026619	-0.0311	31.46	-0.366162448	-0.699718861	-1.08184464
31.59	-0.019516	-0.025295	-0.030907	31.59	-1.742295616	-0.65194962	-1.073696501

Table 3. Average of fNIRS data in Broca's area: the first rest task (left) and English letter task (right)

	First rest task				English letter task			
Time(sec)	ch-17 oxyHb	ch-25 oxyHb	ch-34 oxyHb	**oxyHb Ave**	ch-17 oxyHb	ch-25 oxyHb	ch-34 oxyHb	**oxyHb Ave**
0	-0.663240013	0.260681015	0.23114553	**-0.05714**	-0.782944634	-0.641089694	-1.124991777	**-0.84968**
0.13	-0.036020973	0.188197325	0.255885474	**0.13602**	-0.588265663	-1.288716494	-1.230326518	**-1.03577**
0.26	-0.419241633	-0.247498566	-0.061723049	**-0.24282**	-1.159032778	-0.403614508	-0.799150679	**-0.78727**
0.39	-0.902815127	-0.204058863	-0.351467471	**-0.48611**	-0.612593623	-0.384672777	-0.774579609	**-0.59062**
0.52	-0.596006378	-0.027449772	-0.004812735	**-0.20942**	-1.574598566	-0.562869365	-0.905751971	**-1.01441**
0.65	0.792180189	-0.212032429	-0.436452976	**0.0479**	-1.329107334	-0.62943602	-0.964899856	**-0.97448**
0.78	-1.471425899	-0.14514106	-0.439534915	**-0.68537**	-1.638072425	-0.674354981	-1.220954048	**-1.17779**
0.91	-1.96627872	-0.486200454	-0.362781985	**-0.93842**	-1.338119737	-1.024831123	-1.192836638	**-1.18526**
1.04	-0.891591091	-0.085790303	-0.193950869	**-0.39044**	-0.254474995	-0.720103772	-0.772257601	**-0.58228**
1.17	-0.152297564	0.001125182	0.007515018	**-0.04789**	-1.009581697	-0.741065954	-0.857538634	**-0.8694**
1.3	-0.886891371	-0.157949278	-0.079750277	**-0.37486**	-1.136363542	-0.646429458	-0.728350534	**-0.83705**
1.43	-1.005379594	0.092189809	0.03862993	**-0.29152**	-0.366162448	-0.699718861	-1.08184464	**-0.71591**
1.56	-0.281954532	-0.276975507	-0.298863428	**-0.28593**	-1.742295616	-0.65194962	-1.073696501	**-1.15598**

2.2.3 The fNIRS machine and data analysis

A multichannel continuous wave optical imager (Shimadzu FOIRE-3000), which uses three wavelengths of harmless near-infrared light (780±4nm、805±5nm、830±5nm), was employed to record the hemodynamic response. This non-invasive device has 13 emitters and 14 recepters three centimeters apart from each other, detecting three types of parameters - oxygenated hemoglobin (oxy-Hb), deoxygenated hemoglobin (deoxy-Hb), and total hemoglobin (total-Hb) in 42 areas (channels). While the tasks are on-going, the FOIRE-3000 machine produces a trend graph which concurrently shows how three types of hemoglobin data increase, decrease, or level off (Figure 3).

This graph also helps the researcher to discard any data from particular channels that show the involvement of artifacts due to jerking movements of the participant, or probes popping out of the holder sockets. Out of the three hemoglobin data types, this study focuses solely on the oxy-Hb, following such previous neurolinguistic studies as Guo *et al.* (2011) and Moriai-Izawa *et al.* (2012).

In the first two years, all of the 27 fiber probes were used to collect data from the entire frontal lobe (Figure 4). In 2012, however, this was reduced to 18 probes (Figure 5) since this study only wanted to focus on the left inferior frontal gyrus (Broca's area) and its homologous area in the right hemisphere, as previous studies (e.g. Quaresima *et al.*, 2012; Herrmann *et al.*, 2005; Kameyama *et al.*, 2004) and our own research (Taura *et al.* 2010 and 2011) have discovered the most activation in these areas for linguistic tasks.

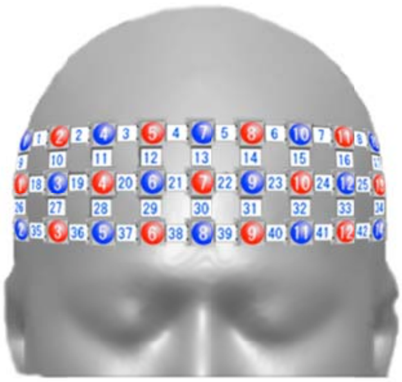


Figure 4. 27 probes/42 channels (2010 & 2011)

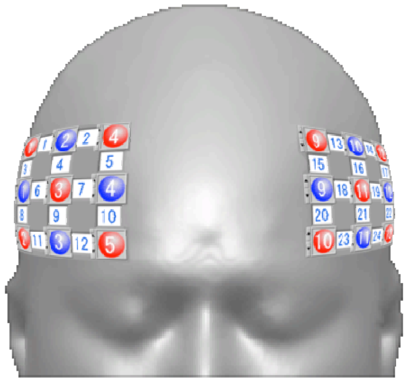


Figure 5. 18 probes/24 channels (2012)

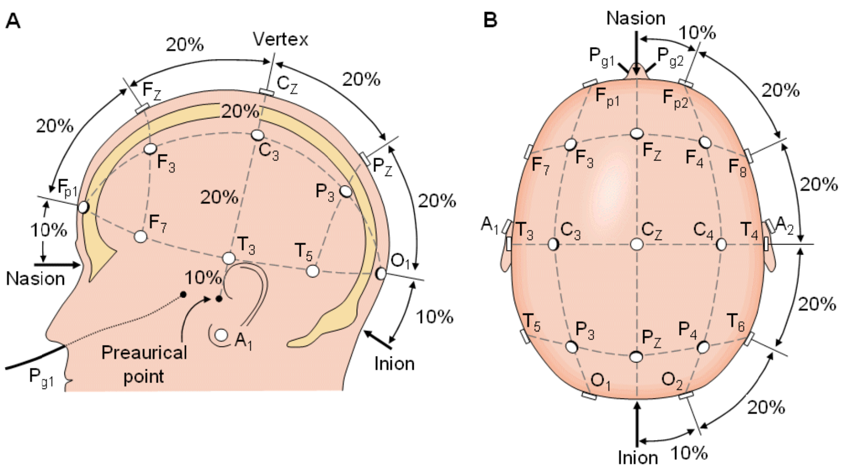


Figure 6. International 10/20 system

Following the International 10/20 system for placement on the head (Jasper, 1958), a flexible brain cap with emitters and recepters was put on the participant's head to cover her frontal cortex, with the lowest probes being positioned along the T3-Fp1-Fz-Fp2-T4 line (Figure 6). After measuring the length between her nasion and inion, recepter hole #8 was placed on the Fpz location (the central position of the T3-Fp1-Fz-Fp2-T4 line). Then both Broca's area and its homologous area in the right hemisphere were visually identified according to the instructions provided by Fukuda (2009; 16).

The logistics of how the fNIRS machine works is roughly (1) to detect the near-infrared rays that are first released from the emitters, penetrate the skull into the cerebral cortex, and return to the recepters, and (2) to estimate how much hemoglobin is concentrated in a particular area of the brain. This is possible since brain activation requires hemoglobin that in turn absorbs the near-infrared rays in the cortex, which means that less rays return to the recepters when coming through the areas where intensive brain activation is taking place. Changes in oxy-Hb, deoxy-Hb, and total-Hb from 130 miliseconds earlier are estimated based on a modified version of Lambert-Beer Law (Seiyama *et al.*, 1988; Wray *at al.*, 1988) which is used as an arbitrary scale unit, fNIRS value of mMmm - molar-concentration multiplied by the unknown length of the optical path since the machine cannot measure optical path length (Hoshi, 2003).

2.3 Procedure

Our participant was shown into a laboratory and seated in a chair with her eyes approximately 30 cm away from the monitor (Panasonic Let's Note CF-F9). First, her head measurements were taken to allow the flexible cap to be placed correctly on her head according to the International 10/20 system (Jasper, 1958). While the cap was being put into place about ten minutes, information was gathered on her language background, right or left-handedness, and self-assessment of the four skills (speaking, listening, writing, and reading) in Japanese and English. Once the cap was ready and the optical fibers from the fNIRS machine were connected up, photos were taken to record the position of the cap at three angles—from the left, right and front. Then, a video clip was shown to inform the participant of what the experiment (VFT) involved. When she was made fully aware of the task, she was told that it was her right to stop the procedure at any time if she felt uncomfortable. Upon completion of the VFT, a three-minute semi-structured interview was conducted to ask her opinions on the task, while the cap and fibers were removed and then she was asked to write the essay for the TOWL-3 analysis for 15 minutes. At the end of the experiment, a token of gratitude (book voucher) was given to her. Prior to the experiment, a consent form (approved by the Ethics Committee at Ritsumeikan University, Appendix 1) was signed by her parents each year to allow her to participate in this study.

3. Results & discussion

3.1 Linguistic aspects

3.1.1 Writing skills

The participant's writing sample from 2010 and a score sheet are included in Appendix 2. The TOWL-3 scores over the three years are summarized in Table 4.

Age-adjusted scores of between 8 and 12 for the CC (contextual conventions: basic English writing rules such as punctuation), CL (contextual language: vocabulary and grammar), and StC (story development) are within the average NS average range while scores over 12 are regarded as above the NS average in TOWL-3. When looking at the Quotient (overall writing scores), scores of between 90 and 110 are within the NS average and over 110 is above average.

Table 4. TOWL-3 age-adjusted scores

sessions	**CC** basic rules	**CL** vocabulary/morphosyntax	**StC** story development	**Quotient** overall
2010 (16;06)	13	15	15	128
2011 (17;06)	13	16	14	128
2012 (18;05)	14	18	14	134

The TOWL-3 scores clearly show (1) that our participant's writing skills were above the NS average, scoring over 12 in CC, CL, and StC and 110 for the Quotient upon return to Japan in 2010, and (2) that her advanced English writing proficiency did not decline for the three years after her return to Japan, which is noteworthy considering the fact that her NS counterparts are only using English at high school where cognitively and intellectually demanding subjects are taught and a more sophisticated style of academic writing is introduced. This suggests that she improved her writing skills over the three years back in Japan and kept abreast of her counterparts who were continuously progressing in their academic writing, too.

3.1.2 Lexical analysis

Levels 1 to 4 words (L1 words being the first thousand words most frequently used by NS) account for over 95% of the tokens used in the writing samples over the three years as shown in Table 5.

Table 5. Lexical level coverage

	types			tokens			token coverage		
word level	2010	2011	2012	2010	2011	2012	2010	2011	2012
Level 1	91	102	82	141	193	166	84.9%	83.9%	84.3%
Level 2	9	20	7	10	25	13	91.0%	94.8%	90.9%
Level 3	6	2	4	8	2	4	95.8%	95.7%	92.9%
Level 4	3	1	4	4	1	5	98.2%	96.1%	95.4%
Level 5	0	0	0	0	0	0	98.2%	98.3%	95.4%
Level 6	0	**1**	0	0	**3**	0	98.2%	99.6%	95.4%
Level 7	0	0	**1**	0	0	**1**	98.2%	99.6%	95.9%
Level 8	0	0	0	0	0	0	98.2%	99.6%	95.9%
Level 9	0	0	0	0	0	0	98.2%	99.6%	95.9%
Level 10	**1**	0	0	**1**	0	0	98.8%	99.6%	95.9%
Level 11	0	0	0	0	0	0	98.8%	99.6%	95.9%
Level 12	0	0	**1**	0	0	**1**	98.8%	99.6%	96.5%
others	1	1	2	1	3	2	0.6%	0.1%	0.5%
off list	2	1	5	2	1	7	1.2%	0.4%	3.6%
total	112	130	104	166	230	197	100.0%	100.0%	100.0%

The words with a frequency level of use over 5 were in 2010 a Level 10 word 'crater' used once and in 2011 a Level 6 word 'tribe' used three times while a Level 7 word 'quest' and Level 12 word 'Martian' were used once each in 2012. This signifies that there was virtually no change in the choice of words - neither an increase or decrease in the number of high level words. A glance at the total number of types and tokens from 2010 through 2012 shows that they both underwent similar change over the three years with a pattern of fluctuation of increases and decreases. On the other hand, lexical density attrition was revealed in the decrease in type-token ration (TTR) from 0.65 in 2010 to 0.57 in 2011 to an even lower 0.53 score in 2012. Thus, while the majority of lexical analyses indicate language retention, lexical density was the sole exception which where attrition occurred.

3.1.3 Accuracy analysis

A 4-M model-based accuracy analysis was conducted and the results are summarized in Table 6. In 2010, there were only two spelling mistakes ('ailiens' for aliens and 'friendliiness' for friendliness) and no morpheme errors at all. In 2011 there were two morpheme errors: one was the wrong choice of preposition 'before me' instead of 'in front of me' and the other was a combined auxiliary verb/spelling error 'wringed in my ears' instead of 'rang in my ears', which are content morpheme and early system morpheme errors, respectively. In 2011 two errors occurred - a content morpheme (preposition) error of 'rumors going on' rather than 'rumors going around' and an outsider late system morpheme (auxiliary verb) error of 'he was left' instead of 'he had left.' Thus, the number and rate of errors underwent virtually no change from 0 (0%) to 2 (0.7%) to 2 (0.8%), although the total number of morphemes fluctuated from 197 in 2010 to 273 in 2011 and 238 in 2012.

Table 6. Morpheme count and accuracy rate based on the 4-M model

	correct			error			accuracy (%)		
content morphemes	2010	2011	2012	2010	2011	2012	2010	2011	2012
noun/pronoun	56	68	65	0	0	0	100	100	100
verb	21	36	23	0	0	0	100	100	100
auxiliary verb	3	0	5	0	0	0	100	N/A	100
adjective/adverb	24	36	30	0	0	0	100	100	97
demonstrative	0	0	0	0	0	0	N/A	N/A	N/A
conjunction	7	7	15	0	0	0	100	100	100
relative	3	5	0	0	0	0	100	100	N/A
preposition	12	22	14	0	**1**	**1**	100	96	**93**
interjection etc.	0	0	0	0	0	0	N/A	N/A	100
total	126	174	152	0	**1**	**1**	100	**99**	**99**

(continues)

(continued)

	correct			error			accuracy (%)		
early system morphemes	2010	2011	2012	2010	2011	2012	2010	2011	2012
article	5	21	9	0	0	0	100	100	100
intensifer	0	0	0	0	0	0	N/A	N/A	N/A
possessive pronoun	7	5	1	0	0	0	100	100	100
determiner: demonstrative	7	0	0	0	0	0	100	N/A	N/A
determiner: demonstrative modifiers	8	4	10	0	0	0	100	100	100
plural "s"	3	14	6	0	0	0	100	100	100
present participle	2	2	3	0	0	0	100	100	100
past participle	0	1	0	0	**1**	0	N/A	**50**	N/A
verb phrase	8	3	2	0	0	0	100	100	100
infinitive (nominal usage)	1	3	1	0	0	0	100	100	100
total	41	53	32	0	**1**	0	100	**98**	100
bridge late system morphemes	2010	2011	2012	2010	2011	2012	2010	2011	2012
possessive "of"	1	2	3	0	0	0	100	100	100
possessive "s"	2	0	0	0	0	0	100	N/A	N/A
formulaic article	3	2	1	0	0	0	100	100	100
formal subject: it/there	2	3	4	0	0	0	100	100	100
copula "be"	5	3	6	0	0	0	100	100	100
parataxis "and"	0	1	0	0	0	0	N/A	100	N/A
infinitive (adjective usage)	0	0	0	0	0	0	N/A	N/A	N/A
total	13	11	14	0	0	0	100	100	100
outside late system morphemes	2010	2011	2012	2010	2011	2012	2010	2011	2012
third person singular	0	0	1	0	0	0	N/A	N/A	100
regular past tense	6	6	6	0	0	0	100	100	100
irregular past tense	4	8	9	0	0	0	100	100	100
"be" verb past tense	4	11	11	0	0	0	100	100	100
auxiliary verb: be/have/do	2	9	10	0	0	**1**	100	100	91
clitics affixes	1	0	1	0	0	0	100	N/A	100
infinitive (adverbial usage)	0	1	2	0	0	0	N/A	100	100
total	17	35	40	0	0	**1**	100	100	**98**
TOTAL	**197**	**273**	**238**	**0**	**2**	**2**	**100**	**99**	**99**

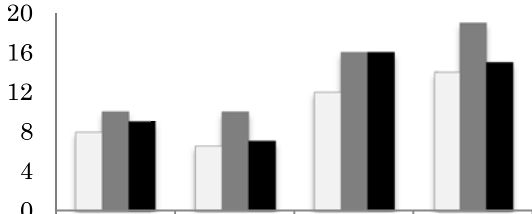
3.1.4 Fluency analysis

The number of morphemes, types, and sentences were (197, 112, and 10) in 2010, (273, 130, and 12) in 2011, and (238, 104, and 14) in 2012. The average number for each constituent produced per minute was calculated by dividing by 15, resulting in 3 yearly changes of 13.1 to 18.2 to 15.9 morphemes, 7.5 to 8.7 to 6.9 types, and 0.7 to 0.8 to 0.9 sentences. The results showed little fluency change over the three-year period.

3.2 Neurolinguistic aspects

3.2.1 VFT behavioural data

The number of words produced during the VFT (verbal fluency task) is summarized in Figure 7. In 2010 the task duration was double the time (60 seconds) of the length of time in the following two years (30 seconds), therefore the number shown in 2010 has been halved for an easier comparison. No linear increase or decrease on any tasks was observed, although 2011 saw a higher number of words uttered in three out of four tasks in comparison to the data from 2010 and 2012.



	Jletter	Eletter	Jcategory	Ecategory
2010	8	6.5	12	14
2011	10	10	16	19
2012	9	7	16	15

Figure 7. VFT behavioural data

3.2.2 VFT fNIRS data

A series of Analysis of Variance (ANOVA) with post-hoc Bonferroni procedures at the alpha level of 5% were carried out on the z-scores converted from the fNIRS raw data and the results are summarized in Figure 8 and Tables 7 and 8.

Figure 8 shows that in 2010 there was significantly more brain activation in Broca's area than its homologous area in the right hemisphere for all of the four verbal fluency tasks (this tendency was more or less the same in 2011 and 2012 as well). We interpreted this as indicative that the participant's main language faculty was in the left hemisphere. The Edinburgh handedness test revealed that she was 100% right-handed, which also lent support to her left hemisphere dominance in language processing. Thus, to make the discussion simpler, our main focus has been placed on the fNIRS data from Broca's area when synthesizing the results.

Previous research (e.g., Kubota *et al.,* 2005; Ehlis *et al,* 2007) indicates that letter tasks involve more brain activation than category tasks due to the neuronal network in the mental lexicon where lexical items are semantically connected: 'brother' and 'sister' are more easily associated or accessed when an umbrella word 'family' is presented than when a prompt letter 'b' or 's' is presented. In fNIRS terms, more oxy-Hb activation is observed on letter tasks than category tasks. Our data in 2011 and 2012 follow this argument but not the 2010 data. However, in the participant's first year back in Japan more effort was needed for the category tasks than letter tasks in both Japanese and English for some reason. This tendency was reversed in the second year and stayed the same in the third year. There is no knowing exactly what triggered the change in the second year because brain activation tells us only what is happening, not why it is happening.

We attempted to look for any other oxy-Hb changes in the second or third year and discovered several. First, a change was noticed in the third year (2012) for the English letter task. In 2010 and 2011, the task resulted in significantly lower concentration of the oxy-Hb in Broca's area than for the Japanese letter task, whereas in 2012 both tasks showed an equal amount of oxy-Hb (Table 7). The English letter task required more oxy-Hb in 2012 than in 2010 and that the Japanese letter task required equal amounts of oxy-Hb in 2010 and 2012. This cold be interpreted as showing that the participant's dominant English language was beginning to attrite to the extent that she needed the same level of energy for English as when she was using her inferior Japanese on the letter task. Thus, the third year change appears to imply attrition in the participant's dominant language of English.

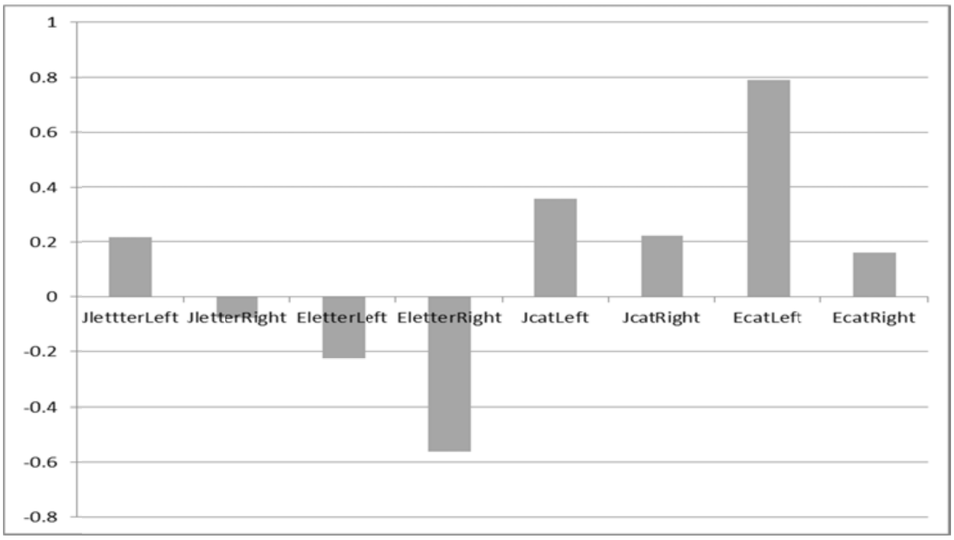


Figure 8. 2010 fNIRS (mMmm) on eight tasks

Table 7. Yearly fNIRS data from both hemispheres on task differences

year		*F value* Broca	Right	fNIRS order in Broca's area	fNIRS order in right hemisphere
2010	F(3,143)=	93.448	51.789	Eletter<Jletter=Jcategory<Ecategory	Eletter<Jletter<Ecategory=Jcategory
2011	F(3,143)=	73.763	67.623	Ecategory=Jcategory<Eletter<Jletter	Ecategory<Eletter=Jcategory<Jletter
2012	F(3,143)=	129.379	119.917	Ecategory=Jcategory<Jletter=Eletter	Jcategory<Eletter=Ecategory<Jletter

($p<.05$)

Table 8. Yearly differences in each hemisphere

task		*F value* Broca	Right	fNIRS order in Broca's area	fNIRS order in right hemisphere
Jletter	F(2,435)=	16.189	65.024	2010=2012<2011	2010<2012=2011
Eletter	F(2,435)=	47.836	81.257	2010<2012=2011	2010<2012=2011
Jcategory	F(2,435)=	17.213	20.607	2012<2011<2010	2012<2010=2011
Ecategory	F(2,435)=	73.471	9.068	2012<2011<2010	2011=2010=2012

($p<.01$)

Secondly, the English letter tasks required significantly more oxy-Hb from the second year and this trend remained the same in the third year as shown in Figure 9 where red indicates a greater amount of brain activation and dark blue shows less activation. A larger amount of oxy-Hb was needed in 2011 and 2012 for the same letter task as in 2010 and this might signal English language attrition.

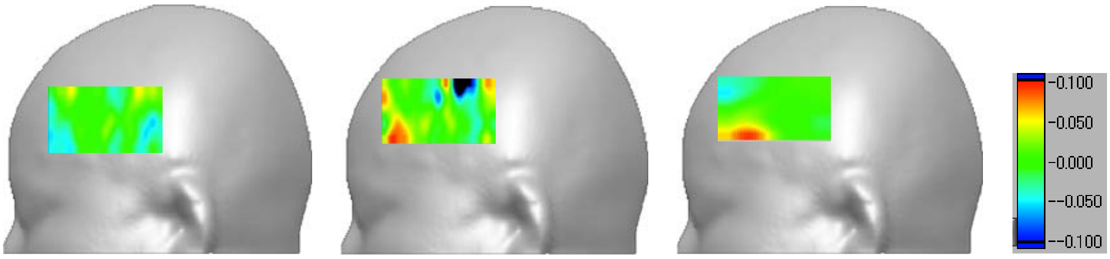


Figure 9. Oxy-Hb in Broca's area during English letter task (left 2010 < middle 2011 = right 2012)

Thirdly, a second year change was revealed on the category tasks. In the first year, the Japanese category task resulted in statistically more oxy-Hb than for the English category task, which mirrors the participant's self-assessment of 3 for English and 2.5 for Japanese as shown in Table 1. However, this tendency was no longer observable from the second year on, when both Japanese and English category tasks required an equal amount of brain activation. This statistically supports the notion that the same amount of brain activation that was required for the Japanese and English category tasks show no dominance of English over Japanese. This identical change is revealed in Table 8 as well in that Japanese and English category tasks required less brain activation in 2011 than in 2010. The table further shows a significantly less activation in 2012 than in 2011. Thus, brain activation gradually decreased from 2010 to 2012, which indicates that, for the participant, category tasks became increasingly easier each year during the three years. What triggered this sudden change in brain activation cannot be answered with the fNRIS data.

4. Conclusion

In order to explore how a bilingual first language is retained and attrited from linguistic and neuroimaging perspectives, we undertook a three-year longitudinal study on a Japanese returnee who was born and raised in the USA for over 16 years. Writing analyses revealed that the participant's writing skills, as assessed by TOWL-3, improved, matching her NS counterparts. Lexical analysis revealed that her English vocabulary remained mostly intact except for the lexical density aspect. With regard to accuracy, she suffered from no attrition in any of the four types of morphemes since her writing accuracy was marked as 99% during the three years. No-attrition was revealed in the writing fluency, either. Thus, for the majority of linguistic variables examined including the writing skills, accuracy, fluency, and vocabulary, language retention was apparent with only a slight decline in lexical density. This might be due to the fact that the participant had undergone her entire formal education in English until she returned to Japan at age 16;06. This is supported by Taura's study (2008), where he examined 64 Japanese-English bilingual returnee children and revealed that the language medium of instruction at school in one's first four years of formal education anchors itself robustly enough to resist attrition from setting in for several years after the language use discontinues.

Meanwhile, the neuroimaging analyses in Broca's area indicated that English attrition became evident in the second year and the dominance of English disappeared in the third year in the letter task, whereas the category task in both English and Japanese began to require the same level of brain activation from the second year on. Therefore, attrition seems to have begun from the second year.

Synthesizing the results from the two lines of enquiry into how a bilingual first language is affected when the linguistic environment drastically changes, the results are very similar to each other in the sense that almost no attrition was observed. However, while the linguistic enquiry only revealed a slight attrition in lexical density, the brain-imaging approach was able to identify significant attrition that took place from the second year onwards in the language centre, Broca's area. Thus, the results seem to indicate the usefulness of using the neuroimaging approach or combining the conventional and neurolinguistic approaches in disclosing the process of language attrition.

This study linguistically examined one participant's writing samples from a variety of angles to a though degree and also rigorously analyzed a vast amount of fNIRS data. However in the future, further research should include multiple participants and the deoxy-Hb and total-Hb brain activation levels for further data analysis.

Acknowledgement and apology

We are grateful to the student whose data we analyzed for this research. Our appreciation also goes to all the students who have taken part in our project since 2010, particularly those who have continuously agreed to participate in the project over the three years. They leniently overlooked our mistake in not obtaining permission from the Ethics Committee at Ritsumeikan University in 2011. This was due to the misunderstanding that the research could continue without asking permission each year as long as our participants and methodology stayed the same as in 2010 when official research permission was first granted. In 2012 we were given official permission from the Committee (Appendix 1) that dated back to the 2011 research. The full details were included in our letter explaining the situation to each participant and their parents prior to the 2012 experiment (Appendix 3). They all showed understanding and agreed to put their signatures on a statement allowing the 2011 data to be included in the entire research project.

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Appendix 1: Approval from the Ethics Committee at Ritsumeikan University

受付番号	衣笠-人-2012-4	通常・~~迅速~~

審　査　結　果　通　知　書

2012 年 8 月 30 日

言語教育情報研究科

教授　田浦　秀幸　殿

立命館大学　衣笠キャンパス
人を対象とする研究倫理審査委員会
委員長　渡辺　公三

以下の課題について、審査結果を通知いたします。
今後の手続きにつきましては、下記のとおりご対応をお願いします。

記

1．申請課題	研究課題名　：　脳科学による言語処理メカニズム解明研究：言語習得と保持・喪失 研究分類　：　一般 研究期間　：　2011年4月1日　～　2017年3月31日
2．申請研究者	所属　職名　氏名 言語教育情報研究科　教授　田浦　秀幸
3．審査結果	○（1）承　認　【承認番号：衣笠－人－2012－4】 （2）条件付承認 （3）変更の勧告 （4）不　承　認 （5）非　該　当

4．修正項目（審査委員会所見）
・審査結果(2)(3) については、承認の条件として、以下の修正を行ってください。
・今後の手続きは、別紙のフローチャートをご参照ください。

5．備考

前回条件付承認（2012.8.3）における下記委員会所見に対し、2012年8月28日付の回答にて申請書類の修正が確認されたため、承認とします。

ただし、既発表論文において事実と異なる記載があったこと並びに長期に亘る研究計画であることから、以下のとおり本委員会への報告を行なうことを要請します。

1) 2013年3月：　”Study in Language Science”vol.3誌に掲載された訂正文
2) 2015年3月：　①研究対象者（グループ）に変化がないか、②使用する機器についての安全性確認、③その他、倫理的な問題の有無について、を記載した実施状況報告書（様式任意）

Appendix 2: 2010 writing sample and TOWL-3 score sheet

[2010 writing sample]

December 21, 3010: It's been exactly ten years since my space team and I left on a journey to outer space. Our mission was to go to Mars and look for life, when we discovered there was a civilization already developing in one of the many craters on Mars. No humans were there; just ailiens that wandered around speaking their own language. From that day on, we decided to stay there and live with them.

Their civilization was something very different compared to ours: meals two times a day and nuts made out of sand. Something very unusual was their cooperation and friendliiness towards other people. Despite the immense size of their community they all respected others. This realization is what brought us to the idea that we could bring this spirit of cooperation to Earth.

Now, ten years have passed from this day, and we've finally found the true meaning of respect. Soon, we will go back to planet Earth, hoping for a better future.

[score sheet]

Section V. Story Scoring

Subtest 6
Contextual Conventions

Score		Items and Scoring Criteria
	1.	All sentences begin with a capital letter 0 = no 1 = yes
	2.	Paragraphs 0 = none, 1 1 = 2 2 = 3–4 3 = 5 or more
	3.	Uses quotation marks (" or ") 0 = no 1 = yes
	4.	Uses comma to set off a direct quotation 0 = no 1 = yes
	5.	Uses an apostrophe in a contraction (e.g., isn't) 0 = no 1 = yes
	6.	Uses a colon, semicolon, or hyphen (:, ;, -) 0 = no 1 = yes
	7.	Uses a question mark (?) 0 = no 1 = yes
	8.	Uses an exclamation point (!) 0 = no 1 = yes
	9.	Capitalizes proper nouns (e.g., Oz, Bob, Italy, Italian, Earth) 0 = no 1 = sometimes 2 = yes, always
	10.	Overall punctuation and capitalization is 0 = poor 1 = average 2 = good
	11.	Number of nonduplicated words misspelled 0 = 6 or more 1 = 3–5 2 = 0–2
	12.	Spelling is 0 = poor 1 = average 2 = good
	Raw Score	

Subtest 7
Contextual Language

Score		Items and Scoring Criteria
	1.	Fragmentary sentence 0 = yes 1 = no
	2.	Run-on sentence 0 = yes 1 = no
	3.	Compound sentences 0 = none 1 = 1 2 = 2–3 3 = 4 or more
	4.	Introductory phrases or clauses 0 = none 1 = 1–2 2 = 3–5 3 = more than 5
	5.	Uses coordinating conjunctions other than *and* (*but, or, nor, for, yet, so*: e.g., "I ran *but* he caught me"; "Do this *or* that") 0 = no 1 = 1–3 2 = 4 or more
	6.	Subject–verb disagreements 0 = more than 1 error 1 = 1 error 2 = perfect, no errors
	7.	Sentences in paragraph(s) 0 = 1 paragraph, 1 sentence 1 = 1 paragraph, 2 or more sentences 2 = 2 or more paragraphs, 2 or more sentences in at least 1 paragraph 3 = 2 or more paragraphs, 2 or more sentences in at least 2 paragraphs
	8.	Composition is composed of 0 = mostly fragments, run-ons, or badly constructed sentences 1 = mostly simple sentences with prepositional phrases 2 = a variety of simple, compound, and complex sentences complete with embedded clauses
	9.	Sentences in composition 0 = are random, no well related to each other 1 = contribute to the development of topic or theme
	10.	Names objects shown in picture 0 = none 1 = 1–3 items 2 = 4 or more items
	11.	Number of correctly spelled words having seven or more letters (count a word only once) 0 = 0–3 1 = 4–7 2 = 8–14 3 = 15 or more
	12.	Number of words with three syllables or more that are spelled correctly (count a word only once) 0 = 0–2 1 = 3–4 2 = 5 or more
	13.	Uses *a* and *an* appropriately 0 = uses neither *a* nor *an* 1 = uses *a* appropriately at least once 2 = uses *an* appropriately at least once
	14.	Vocabulary selection 0 = sparse, immature 1 = more or less adequate 2 = rich, mature
	Raw Score	

Subtest 8
Story Construction

Score		Items and Scoring Criteria
	1.	Story beginning 0 = none, abrupt 1 = weak, ordinary, serviceable 2 = interesting, grabbing
	2.	Story somehow relates to picture 0 = no 1 = yes
	3.	Definitely refers to a specific event occurring before or after the picture 0 = no 1 = yes
	4.	Story sequence 0 = none, a series of random statements 1 = rambles, but has some sequence 2 = moves smoothly from start to finish
	5.	Plot 0 = none, incoherent, statements in random order 1 = weak, meager, spotty 2 = logical, complete
	6.	Characters show feelings/emotions 0 = no 1 = some emotion/low-affect story line 2 = strong emotion clearly evident in at least one character
	7.	Expresses some moral or philosophic theme 0 = no 1 = yes, but weakly stated, inferred 2 = overtly, clearly stated
	8.	Story action or energy level 0 = no action 1 = boring, tedious 2 = run-of-the-mill, predictable 3 = exciting, interesting
	9.	Story ending 0 = none, abrupt 1 = weak 2 = logical, definite ending
	10.	Prose is 0 = immature 1 = ordinary, serviceable, matter-of-fact 2 = artful, stylish
	11.	Story is 0 = dull, merely describes picture 1 = simple, straightforward 2 = interesting, unique, coherent
	Raw Score	

Appendix 3: Letter to participants' parents

「脳科学による言語処理メカニズム解明研究」プロジェクト参加ご依頼とお詫び

立命館大学・大学院
言語教育情報研究
田浦秀幸
2012.9.1

関西学院千里国際中等部・高等部・関西学院大阪インターナショナルスクールの保護者の皆様へ

私ども、立命館大学院・言語教育情報研究科では、学内の研究強化プログラム採択を受け、2010度よりバイリンガル対象の「脳科学による言語処理メカニズム解明研究」プロジェクトを皆様のご協力を得て２年間無事遂行することが出来ました。本年度もご協力をお願いするにあたり、お詫びがございます。

2010 度は立命館大学の倫理審査を経て実験を行いましたが、2011 年度からの継続研究に関しては 2012 年 8 月 30 日付けの（衣笠 - 人 -2012-4）にて承認を得るという手続上の不手際(下記ご参照ください)がございましたことをお詫び申し上げます。実験手法に関しては全く初年度と変化無く、お子様の人体に影響は全くございませんので、ご安心ください。ただ、この不手際により今年度以降の実験参加に不同意の場合は、本同意書を提出なさらないことで、そのご意志をお示しください。

[調査内容]
< 実施場所 > 千里国際学園・プラネタリウム室
< 調査内容 > 約 1 時間の調査で行う項目は次の通りです。
1. 言語背景・利き手アンケート
2. 光トポグラフィー検査（連想ゲームを１０分行います）
< 期間 > 2012.9 月 14 日より 23 日。縦断研究ですので学校卒業時まで毎年 9 月。
小学校から中学校、中学校から高等学校進学時には再度実験参加のご意志をご確認します。
< 謝礼 > 調査参加謝金として、交通費込みで図書券 5,000 円分をお渡しします。
< 検査方法 >
1. キャップをかぶり、その間に連想ゲームをします。
2. 光トポグラフィー検査では、人体に全く無害な光をあてて脳内の血流を観察します。赤ちゃんにも使える最も安全な脳検査方法です（既に多くの研究が新生児対象に行われています）。
3. 万が一検査中ストレス等を感じた場合はその旨申し出て下さい。いつでも中止します。
（各参加者の方にはこの点を再度ご確認後実験を開始しております）
< データ開示 >
本研究については学術成果として公表されますが、検査データの取り扱いは、インターナショナルスクール児童・生徒や千里国際の帰国生及び一般生・公立中学の生徒の年齢別の平均として公表され、個人が特定されるようなデータは一切公表されません。立命館大学大学院・言語教育情報研究科の研究紀要は毎年 3 月に発刊されておりますが、本実験結果は 2011 年 3 月の vol.1 及び 2012 年 3 月の vol.2 誌上に論文として掲載しております。昨年度ご協力頂いた参加者の方には vol2 を 1 部お渡しいたします。
< 保険 >
実験場所への交通機関での移動中及び実験中の不慮の事故（この機器の作成元である島津製作所のお話では、事故は過去 1 件もございませんし、過去 2 年間の我々の研究中にも一切ございませんでした）に対する保険に加入させていただきます（費用はこちら負担です）。

[2011 年度実験実施の際の不手際]

本研究開始時 2010 年度には立命館大学「人を対象とする研究倫理審査委員会」の承認を得ておりましたが、2011 年度の継続実験につきましては承認プロセスを経ずに実施してしまいました。昨年度にさかのぼり、2011 年 4 月 1 日より 2017 年度 3 月 3 日までの縦断研究に関する倫理審査の承認は 2012 年 8 月 30 日付け（衣笠 - 人 -2012-4)で得ております。しかしながら、昨年度はこの承認を経ずに行った研究でありますので、2011 年度の研究参加協力の撤回がございましたらお申し出ください。その際、2012 年 3 月に発刊された「言語科学研究 vol2」に掲載された研究データからも削除を希望されます場合は、「言語科学研究 vol.3」誌上にて、論文の撤回･取り下げを明記させて頂きます。

この点に関しまして不手際を深くお詫び申し上げます。参加不承認につきましては、下記回答書にお書き下さるか、本年度の実験期間中（9 月 14 日から 23 日）に昨年度の研究成果の論文（言語科学研究 vol.2)をお渡ししますので、その際に口頭でお伝えください。

[不参加の自由]

今後の継続研究につきましては、毎年度参加ご希望調査を行いますので、いつの段階でも研究参加の同意撤回をして頂いて結構ですので、毎年の希望調査の際、その旨お伝え下さい。

[お子様の参加意思の確認]

毎年の参加ご協力の依頼の際には、宛先を保護者の方及び参加者の児童･生徒様にしてありますが、実験時には必ずご本人に再度参加のご意志を確認することを継続いたします。

更に、現在小学生である研究参加者が中学校入学時には、保護者の方に加えて参加者ご本人からも実験参加意思のご確認をさせて頂きます。

[責任者・連絡先]

この調査についてのご質問やお問い合わせがありましたら、こちらまでお願いいたします。

立命館大学大学院言語教育情報研究科　田浦秀幸研究室
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[苦情等の窓口]

今回の研究に関する苦情等ございましたらご遠慮なく立命館大学・リサーチオフィスまでご連絡ください(Fax:075-465-8371　E-mail: k-rinri@st.ritsumei.ac.jp)。