LT4254 Psycholinguistics of Reading

Group Project Final Proposal

Mapping the reading circuitry for skilled pre- and post-lingual deaf Chinese readers: An fMRI study of semantic and phonological processing

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1. Introduction

A number of previous studies have attempted to document the mapping of neural circuitry for normal hearing readers (Dehaene, 2009; Jobard, Crivello, & Tzourio-Mazoyer, 2003; Price, 2012; Price & Mechelli, 2005; Pugh et al., 2001). However, the examination of deaf readers is difficult due to the potential differences affecting reading skills (Karchmer & Mitchell, 2003; Mayberry & Lock, 2008; Powers, 2003).

A previous study “Mapping the reading circuitry for skilled deaf readers: An fMRI study of semantic and phonological processing” (Karen et al.,2013) has been conducted to investigate the neural circuitry of English deaf readers in reading written words. However, the result may differ among languages. Chinese and English differs in multiple linguistic features, including character composition, syllable distribution, and suprasegmental features (Tan et al., 2005). English is composed with alphabets but Chinese forms from strokes to radicals to characters (Tan et al. 2005). English words can contain more than one syllable while Chinese characters are monosyllabic. English is a stressed accent language whereas Chinese is a tonal language. Previous studies have examined differences in processing of written words in Chinese and English (e.g. Tan et al., 2005; Wu et al., 2012). This may suggest the possibility of variations in neural circuitry for reading Chinese and English.

Therefore, we propose a new study with similar experimental set-up to Karen’s study (2013) but modified it for Chinese deaf readers in the aim of finding the corresponding reading circuitry of deaf readers in reading Chinese. In the proposed study, we attempt to investigate the semantic and phonological processing of written words by three groups of highly skilled readers, pre-lingual deaf readers, post-lingual deaf readers and normal hearing readers. We attempt to further investigate the semantic and phonological processing segregation and pattern neural dissociation with regards to the time of deafness. With the difference of linguistic features in Chinese and English, we attempt to examine the above pattern regarding semantic and phonological processing shows similarity in Chinese readers' neural circuitry.

By locating the neural circuitry of hearing-impaired people in reading Chinese words, the importance of auditory input in reading comprehension could be ascertained. This could reveal the usefulness of hearing device.

2. Literature reviews

Studies regarding reading circuitry for adult hearing readers have located a relatively clear neural pathway (Dehaene, 2009; Jobard, Crivello, & Tzourio-Mazoyer, 2003; Price, 2012; Price & Mechelli, 2005; Pugh et al., 2001). It is suggested that both ventral and dorsal neural pathways in a left-lateralized network were recruited by adult readers. However, whether the reading circuitry is the same for explaining reading comprehension in deaf is still under debate (Emmorey et al. ,2013). Studying the reading circuitry in deaf is difficult since a variety of factors, such as onset time of language learning and socioeconomic factors, could greatly vary reading levels of deaf readers (Karchmer & Mitchell, 2003; Mayberry & Lock, 2008; Powers, 2003). Further research needs to be done on locating the actual mechanism of reading circuitry in deaf subjects.

It is found that left inferior prefrontal cortex (LIPC) is commonly involved in the reading circuitry. Concerning the activation of LIPC in hearing readers, some studies showed a clear anterior–posterior separation between semantic and phonological processing (e.g., Fiez, 1997; Poldrack et al., 1999), while other studies showed absent or weak functional segregation (e.g., Barde & Thompson-Schill, 2002; Price et al., 1997). Further studies found that there is no clear segregation within their LIPC at a stringent threshold. Both anterior and posterior LIPC contribute to both processings in various extents (Devlin, Matthews, & Rushworth, 2003; Gold & Buckner, 2002; see also Emmorey et al. ,2013). In contrast, the semantic and phonological processing show a clear anterior–posterior segregation in deaf readers, which indicates that skilled deaf readers develop the same pattern of neural organization within LIPC as hearing readers but at a reduced threshold (Emmorey et al. ,2013).

While the same pattern of neural organization was found, one may wonder if similar development of phonological representation could also be found in deaf subjects. And more specifically, with the deprivation of auditory speech input which affects reading abilities, any consequences on the development of their reading abilities would be found.

For phonological representation, it is suggested that prelingual deaf subjects develop phonological representations under the resort of visual and articulatory inputs other than auditory. Some studies have shown that deaf subjects were aware of various aspects in phonology, even though in a lesser degree than hearing individuals. This kind of phonological representation includes not only phonological structure, but also phonological similarity manipulations (Hanson and Fowler, 1987). They were able to make rhyming judgements on printed words and even generate correct rhymes regardless of the orthographic structure of the words in English (Charlier and Leybaert, 2000; Hanson and McGarr, 1989).

The abovementioned phonological representation of words may to a certain extent correspond to a detailed articulatory representation of the words (Charlier and Leybaert, 2000; Hanson and McGarr, 1989). Other studies also support the view that deaf individuals may rely more on articulatory than acoustic representations of speech for phonological processing tasks (MacSweeney et al., 2009). For congenital deaf subjects, it is suggested that the functional brain circuit of reading may change due to underspecified phonological representations development under the lack of child speech experience. Supporting evidence is provided in a fMRI study by Aparicio, Gounot, Demont, and Metz-Lutz (2007). Their study of rhyme judgment task showed that phonological judgement was significantly more difficult for deaf than for hearing participants, which revealed significant differences in their reading circuit. In the comparison with the hearing groups, it is found that the deaf group had a greater activation in the left inferior parietal cortex and left IFG (Brodmann Area (BA) 44). This reflected that deaf readers relied on grapheme-to-phoneme conversion processes that map orthography to phonology, while hearing readers relied more on a ‘‘direct’’ route which maps orthography to lexical–semantic representations. However, other studies also showed that a progressive decline in the accuracy of auditory-phonological representations could slowly bias the approach to written material towards the use of the direct route (Lazard et al. , 2010).

It is clear that hearing and deaf readers do have different phonological representation and use different routes in reading. However, how the auditory speech impacts the neural systems for more proficient reading requires further investigation.

Differences in terms of deprivation of auditory speech can be found in two types of deaf subjects: prelingual and postlingual deaf. Pre-lingual deaf refers to congenital hearing loss or whose hearing loss occurred before they learned to talk (Lee et al. , 2001). Post-lingual deaf refers to someone whose hearing loss occurred after the acquisition of speech and language, usually after six years old.

Apart from the time of hearing loss being diagnosed, reading proficiency need to be taken into account in regard to investigation of reading. Considering skilled and unskilled readers, Aparicio et al. (2007) suggested more right hemisphere involvement for unskilled deaf readers compared to hearing readers. Both groups engaged the left inferior frontal gyrus (BA 45) during implicit reading; however, the less proficient deaf readers also engaged the right middle frontal gyrus (BA 46/9), and exhibited no superior or middle temporal activation (Corina, Lawyer, Hauser, and Hirshorn, 2013).

Most of the previous studies shed lights on reading English but results vary from languages to languages. Therefore, to consider the different linguistic features between Chinese and English, it is suggested that Chinese, as a logographic and monosyllabic language, requires a direct orthography-to-phonology mapping at the syllable level. Previous studies proposed that the left dorsolateral frontal system serves as long term storage center for phonological representation of words, and thus is responsible for the addressed phonology in Chinese (Siok et al., 2003, 2004; Tan et al., 2001a, 2003, 2005). However, English demands a different phonological mapping. English as an alphabetic and multisyllabic system operates grapheme-to-phoneme conversion. The posterior of temporoparietal regions are reported to be responsible for this assembled phonology (Booth et al., 2004; Eden et al., 2004; Poldrack et al., 2001; Price, 2000; Shaywitz et al., 1998; Simos et al., 2000, 2002; Temple et al., 2001, 2003; Tan et al., 2003,2005; Xu et al., 2001, 2002).

For Chinese, the role of the left middle frontal gyrus is for the intensive visuospatial analysis of Chinese logographs (Tan et al., 2001a, 2001b) and the coordination of different processing (Tan et al., 2000, 2001b). The activation in left middle/inferior frontal gyrus showed simultaneous occurrence with the left premotor cortex and supplementary motor area indicates motoric representation or articulatory rehearsal of vocally/sub-vocally phonological information of the characters (Kuo et al., 2004).

In the dimension of processing, neural circuit differs in semantic and phonological processing. It is suggested that anterior regions in the left inferior prefrontal cortex are associated with semantic processing, whereas posterior regions are associated with speech-based phonological processing (Buckner, Raichle, & Petersen, 1995; Gold & Buckner, 2002; Poldrack et al., 1999; Price, Moore, Humphreys, & Wise, 1997). In addition, bilateral inferior parietal cortices are associated more with phonological processing than semantic processing (McDermott, Pet- ersen, Watson, & Ojemann, 2003; Price et al., 1997).

The left fusiform gyrus, known as visual word form area (VWFA) for word recognition (Cohen et al., 2002) is suggested to be associated with word form recognition and relaying the information to regions central to both phonological and semantic processing in multiple languages (Jobard et al., 2003). For Chinese in particular, the activation is not limited to left fusiform but bilateral (Bolger et al., 2005; Tan et al., 2005). A previous study attempted to explain it as the left fusiform is responsible for identifying radicals whereas right fusiform is responsible for radical arrangement within a character (Liu and Perfetti, 2003).

The spatial locations also differ slightly within the ventral temporal occipital system, which is involved in word recognition (Cohen et al., 2000). The left medial fusiform gyrus is more associated with Chinese while the left lateral fusiform cortex is associated more with English (Tan et al., 2005). Dietz et al. (2005) suggested that the left posterior fusiform cortex is universally responsible for the feedback of phonology to orthography.

Studies have suggested multiple regions associated with articulatory motor of speech. Some studies relate left insula to motor planning of articulation (Dronkers, 1996; Price, 2010; Wise et al., 1999). This is, however, still under debate. Other studies suggested posterior inferior frontal gyrus and the ventral precentral gyrus are related to articulatory-motor coding of speech (Guenther, Ghosh, & Trouville, 2006).

The superior temporal gyrus, mainly in the right hemisphere, is suggested to be associated with tonal representation of Chinese logographs (Tan et al., 2001a) and perception of intonation of speech (Zhang et al., 2010). Previous studies further suggested that the left inferior parietal lobule has a function to store phonological information in working memory (Fiez et al., 1996).

For semantic processing, studies have provided indication of semantic representations. The left middle temporal gyrus is suggested to include semantic representations (Booth et al. 2002, 2006). The function of the anterior ventral part of the left inferior frontal gyrus is to access, maintain and manipulate the above semantic representations.

3. Hypothesis

In accordance with previous studies, it is hypothesized that the overall degree of activation in brain region during reading processing will be the greatest in normal hearing group, followed by post-lingual hearing-impaired groups and pre-lingual hearing-impaired readers. Specifically, the degree of activation will be observed differently in the phonological processing for the three groups of participants but similarly in the semantic processing. Considering the activation in phonological processing, it is predicted that greater activation in the articulatory-motor region will be found in pre-lingual hearing-impaired readers while the degree of activations in post-lingual hearing-impaired resembles that in normal hearing counterpart.

4. Methodology

4.1. Participants

We are targeting three groups of participants: pre-lingual hearing-impaired readers, post-lingual hearing-impaired readers and normal hearing readers. Each group will include 10 adults, aged 18-65. All of them should be native Cantonese speakers, right-handed and without any emotional and mental disorder and/or other disability. As the tasks involve reading, they must have normal or corrected-to-normal vision. For those wearing glasses, they are recommended to wear but a limited set of non-metallic correction glasses will be provided if needed. The two groups of hearing-impaired readers are expected to be severe to profound hearing loss, more than 70dB, but currently without using any hearing device, including hearing aids or cochlear implant. The way of daily communication is expected to be consistent among the hearing-impaired participants, either using sign language or speech most of the time. Pre-lingual hearing-impaired readers are defined as diagnosis as deaf before speech and language development while post-lingual is those diagnosed as deaf after the development, normally the age of six. For the control group, they are expected to be normal hearing, without any history of hearing impairment.

A questionnaire on reading preferences and habits will be conducted to ensure the similar exposure to the written language of all three groups of participants (Emmorey et al. ,2013). Several tests will also be undergone in order to select the most suitable candidates for the experiment. Raven's Progressive Matrices which measures the nonverbal intelligence will be adopted as an IQ test (Yeung, Ho, Wong, Chan, Chung, & Lo, 2012). The Standardized Graded Character Naming Test (HKGCNT) (Leung, Chang, & Kwan, 2007) is going to be used for examining the reading ability of the participants. The Hong Kong Cantonese Receptive Vocabulary Test (Wong, Ciocca, & Yung, 2009) will be used to assess the vocabulary ability of the participants. The Hong Kong Test of Specific Learning

Difficulties in Reading and Writing (Hom Chan, Tsang, & Lee, 2000) will be used for testing the participants' phonological awareness. Three groups of participants are expected to have the alike performance in the first three tests but perform differently in the last test.

4.2. Equipments and Setting

A 3 Tesla MRI scanner, and an MR-safe 2-Buttons Yellow Blue response box will be used to collect the MRI and behavioural data in the study. The MRI scanner is able to capture clear brain activity images. The MR-safe response box is made of plastic, non-magnetic, and non-electronic materials so as to ensure safety and avoid additional noises to the MRI images.

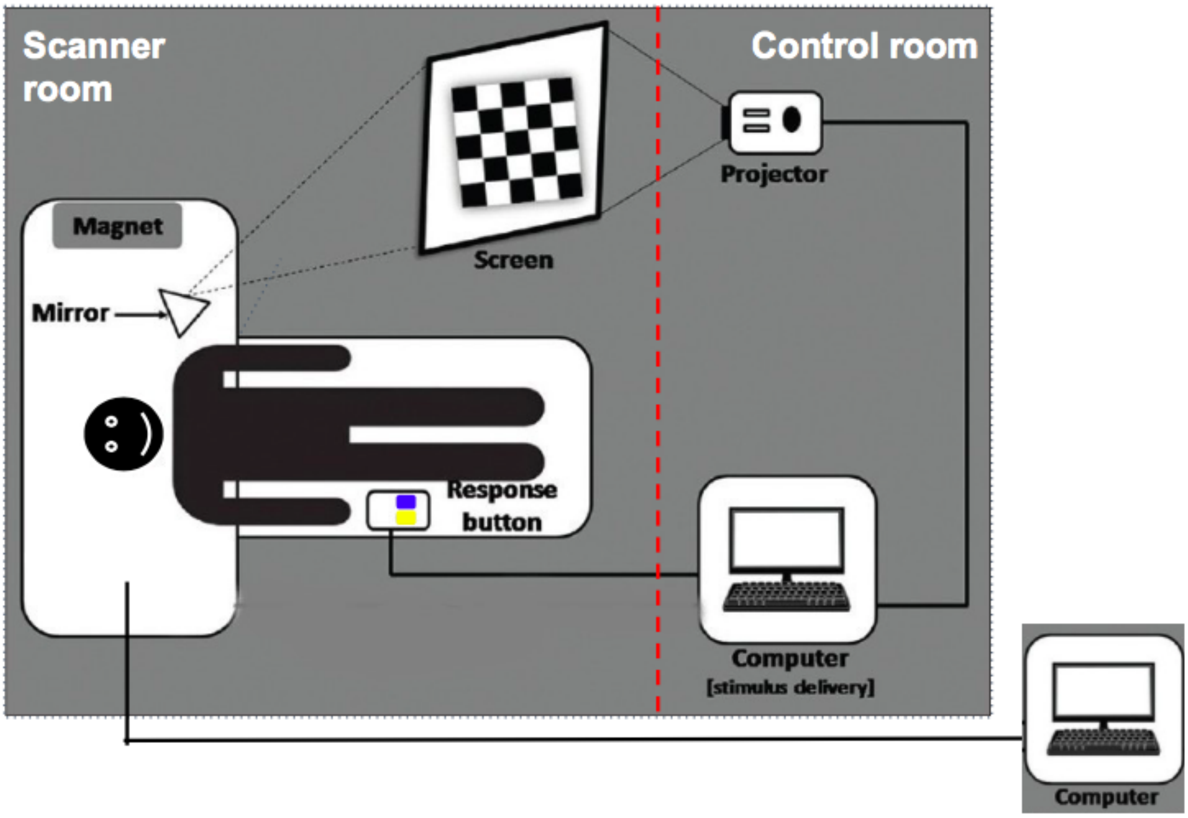

Figure 1. The draft setting for the experiment[1]

The exemplar of experimental setting is shown in figure 1. In the control room, there are two Apple MacBook Pros and a projector. One of the MacBook Pros is used to send out the stimuli and collect the behavioural data, i.e. response time and accuracy. Another one is used to obtain the MRI images. In the scanning room, a non-metallic 72 x 57(inch) projection

[1] This draft setting take James,Rajesh, Chandran, & Kesavadas. (2014, p13) as reference.

screen is placed at the end of the scanning bed. The computer in the control room sends the stimuli to the projector. The stimuli are projected on the screen. Participants will be instructed to read the stimuli words from the reflected images on the mirror, which is located above the head coil. They are required to respond by pressing the response box's buttons, which is placed on right-hand side of the participants.

4.3. Materials

There will be three tasks in the study: the rhyme judgement task, the category decision task, and baseline task. Some criteria are taken into consideration in the word selection for these tasks. Considering the factor of the word frequency and the age of acquisition, all the words are extracted from "Hong Kong Chinese Lexical Lists for Primary Learning". Numbers of strokes of each stimuli word are controlled within 5 to 15. As shown in figure 2, the stimuli appear in the middle of the mirror. These stimuli are displayed on a white background in 100-point font size (except the enlarged words in the baseline task) with the font style "Simsun" and black in color.

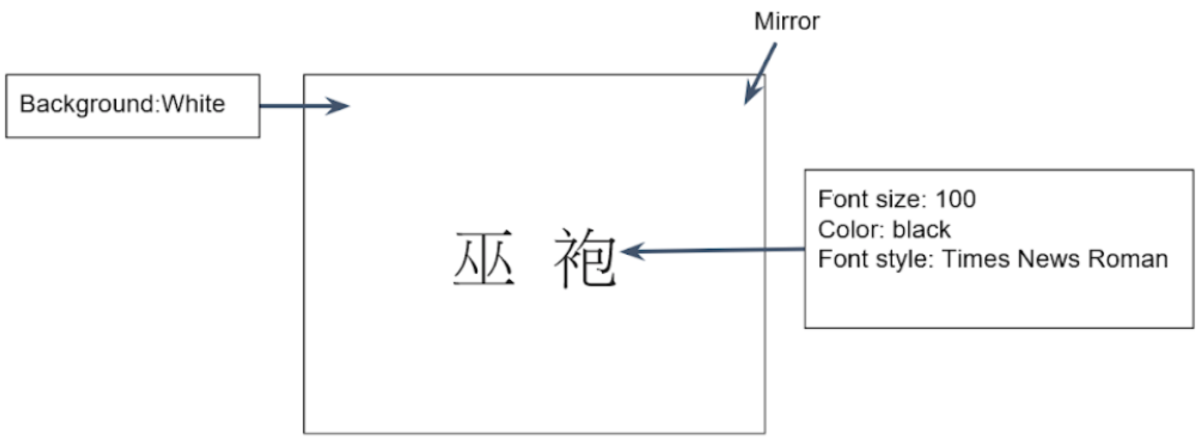

Figure 2. A demonstration of the stimuli appears in the mirror

4.3.1. Task 1: The Rhyme Judgement Task

The rhyme judgement task (Sergent et al., 1992) is used to trigger the phonological processing of words. The participants are required to judge whether the two words are rhyme. A total of 112 pairs of words with CV structure will be used, 56 rhymes and 56 non-rhymes.

The target rhyming pairs are minimal pairs which vary only in consonants but keep consistent in vowels and tones. Stimuli are separated into two sets, and the number of the rhyming pairs (28 pairs) are evenly distributed. Some examples are listed below:

Word 1	IPA	Word 2	IPA	Type
巫 (witch)	/mou21/	袍 (robe)	/p^{h}ou21/	Rhyme
沙 (sand)	/sa:55/	花 (flower)	/fa:55/	Rhyme
雨 (rain)	/jy:23/	柱 (pillar)	/ts^{h}y:23/	Rhyme
弟 (brothers)	/tɐi33/	包 (bun)	/pa:u55/	Not rhyme
符 (symbol)	/fu:21/	書 (book)	/sy:55/	Not rhyme

Table 1. Examples of tests words using in the rhyme judgement task

4.3.2. Task 2: The Category Decision Task (living or non-living)

The category decision task (Wagner et al., 1997) is used to bring about the semantic processing of words. Participants are required to judge whether the reference of the disyllabic vocabularies are living things in the real world. A total of 112 disyllabic vocabularies will be used as stimuli, 56 living things and 56 non-living things. They are separated into two sets, and the number of the disyllabic vocabularies that refer to living things in the real word (28 vocabularies) are evenly distributed. Some examples are presented as following:

Disyllabic vocabularies	IPA	Type
青蛙 (frog)	/tsʰɛ:ŋ55 wa:55/	Living
狐狸 (fox)	/wu:21 lei21/	Living
雪條 (ice-cream)	/sy:t2 tʰi:u25/	Non-living
恤衫 (shirt)	/sɵt55 sa:m55/	Non-living
氣球 (balloon)	/hei3 kʰɐu21/	Non-living

Table 2. Examples of tests words using in the category decision task

4.3.3. Task 3: The Baseline Task

The baseline task is used as control task. The participants are required to judge whether the two words in a pair are in same font size. There are 112 pairs of words. Half of them are same size and half are in different size. The front size of enlarged words is 200. Stimuli are separated into two sets, and the number of the unmatched front size pairs (28 word pairs) are evenly distributed.

4.4 Procedure

The procedure will be introduced in three stages: before experiment, during experiment rand after experiment.

4.4.1. Before experiment

Participants are required to sign an experimental consent form which indicates their voluntary participation and agreement on using the data for academic purpose before the experiment. Aims, procedures and potential risks are presented on the consent form and will be explained by the researchers so as to ensure their understanding about the experiment. A health questionnaire will be filled in by the participants in the purpose of confirming their health condition is suitable the experiment and ensuring their safety during the experiment. Especially, they have to affirm that they have no metal items and not in pregnancy and breastfeeding for safety reason. Metal detector scan through everyone who will enter the scanner room to make sure no metal objects.

Signals/ Symbols[2]	Meaning
押韻?(Rhyme?)	To judge whether the word pair rhyme in next 42 seconds.
生物?(Living?)	To judge whether the reference of disyllabic vocabularies in real world is living thing in next 42 seconds.
大小相同?(Size?)	To judge whether the words in a pair are same size in next 42 seconds.
凝望 (Fixation)	To look at the cross in next 42 seconds.
?	Remind the participants to give response.
+	To look at the cross.
Blue button (response box)	If the answer is 'Yes', use the index finger to press the blue button.
Yellow button (response box)	If the answer is 'No', use the middle finger to press the yellow button.

[2] In the experiments, only Chinese version will be shown. English is provided for the written report.

Table 3. Signals, symbols and the corresponding responses in the experiment

A briefing session introducing the signals, symbols and corresponding responses, as presented in table 3, during the experiment will be conducted prior to the experiment in written form and/or Cantonese sign language. They are required to react as quickly and accurately as possible for measuring the response time and accuracy. They are also encouraged to give responses regardless their certainty to the answer . They are also reminded not to move their head during scanning for capturing better images. A pair of ear plug will be provided in order to prevent the noise from distraction.

4.4.2. During experiment

The experiment will be carried out in block design. In figure 3, a block contains a 3-seconds cue signal, a 42-seconds task (or fixation) and a 15-seconds rest. A cycle consisting four blocks lasts for 4 minutes.

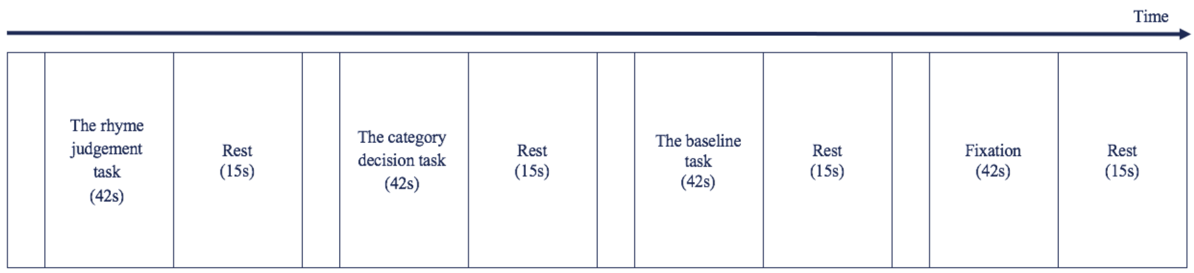

Figure 3. Block design of the experiment

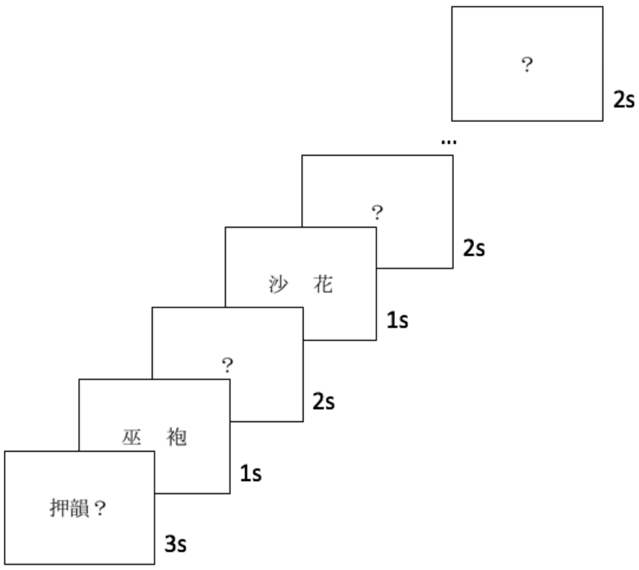

Figure 4. Procedure of the rhyme judgement

The procedure of each task is shown in figure 4. The 3-seconds cues before the tasks remind participants what they need to consider in the next 42 seconds. To insure the blood flow of the brain in the related areas is at the highest level, 14 stimuli appear one by one within 42 seconds, i.e. 3 seconds per stimulus. Each stimulus appears only for 1 second, followed by a question mark which appears for 2 second as a reminder of answering question. Participants can give response once the stimulus appears and before the question mark disappears. After completing an experimental task, the screen become entirely white which indicates a 15-seconds resting time. Another block of test will be launched after 15 seconds and operated in the same way as the first task. A 42-seconds fixation block which requires participants to look at the 'cross' sign displayed on the screen will be given after completion of three experimental tasks for stopping word processing and turning brain activities back to normal level for the next cycle.

To avoid participant's prediction and habitual responses to the stimuli, the sequences of three blocks, including the experimental blocks and control block, will be reordered. A 10-minutes short break is given after cycle 4 to preclude the influence of participants' tiredness and boredom to the judgement. The whole experiment will end after cycle 8.

To make sure that the participants understand their task in the experiment, a trial test will be given before the experimental materials presented. MRI images will not be captured but accuracy will be monitored. Whole set of trial test will be repeated if more than three responses are given. The materials used in trial test will not be as the same as used in the experiment.

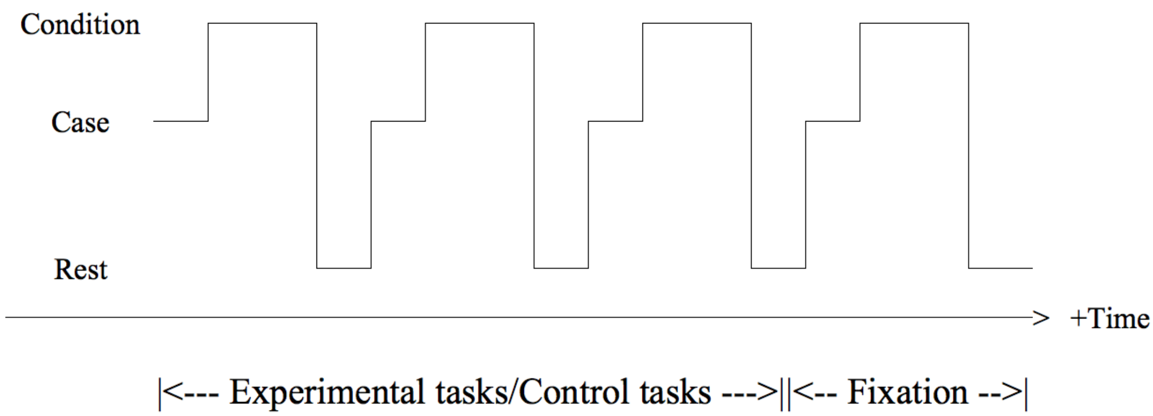

Figure 5. Diagram showing the procedure of getting MRI image

4.4.3. After experiments

After experiment, the investigator will ask the participants if any words in the experiment are unfamiliar to them. The data of the unfamiliar word will be not further analysed. The estimate time for completing the whole set of experiment is 46 minutes, including the break.

4.5. Measurement

Two types of data will be collected and measured in the experiment: behavioural and neuroimaging.

For the behavioural data, response time and accuracy will be considered. The comparison will be made across participant groups in three experimental conditions and across the experimental condition within participant groups. Accuracy data will help screen out data with high error rate which will then not be taken into account.

Regarding neuroimaging data, the MRI data will first be preprocessed and normalized by software. As a result, a set of neural images from the same task in different cycles will be obtained and further processed. First, the baseline data will subtract the fixation data and give out the image in non-linguistic processing. Then, phonological processing images will be obtained by subtracting the non-linguistic processing images from the set of images in rhyme judgement data. Finally, neuroimages from semantic processing will be taken from the subtraction of the image in category decision task by the non-linguistic processing. The images will be used for comparison in terms of degree of activation and regions of activation across the participant groups and processings.

5. Implications

The result of the study is going to contribute to the further study of neural mapping in reading Chinese words and that of hearing-impaired people. In the aspect of neural mapping, the result of our study will give out the area of activation in reading in both normal hearing and hearing-impaired readers which helps with our understanding of the relations between the neural network in brain and processing involved in reading Chinese. The result can be used to compare with previous studies and inspires new research. More importantly, as it focuses on the reading processing of hearing-impaired readers, the result can suggest the importance of auditory input in reading Chinese, which underlines the usefulness of hearing device.

6. Limitations

Despite our effort in minimizing the variation between variables, some unavoidable parts are not able to be solved in our experiment. One potential limitation is the large age difference of our participants. The design of our study requires participants to be either prelingual and postlingual hearing-impaired; thus, the age requirement has to be set as 18-65 for easier recruitment of studied subjects. Other than that, another limitation is one of the tests used to screen out participants. The Hong Kong Cantonese Receptive Vocabulary Test (Wong, Ciocca, & Yung, 2009), which is used to examine the vocabulary size of the participants, is designed for 2-6 year-old children. The vocabulary size may not be sufficient to cover all vocabularies in the experiment. However, there is no other vocabulary test that is more suitable to the experiment. Another limitation is observed in our experiment materials. As we consider much of the factors regarding frequency and age of acquisition, vocabularies that can be used are constrained. With consideration of such issue, our decision of the final set of stimuli was eventually made in the expense of less influential factors such as number of strokes and orthographic structure. Finally, it is worth noting that many ongoing neuroscience studies are still exploring the boundaries between brain regions and functions of each brain region. Our study is unable to tell the exact regions that are responsible for a specific function.

7. References

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