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A Pilot Investigation of Measuring Language Learning Aptitude in Adults Neurophysiologically

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***Abstract*—The ability to learn a new language is a must for adults to adapt to jobs that require rapid mastering of an unfamiliar language under a globalization context of business and management. The talent in learning a new language has been conceptualized as language learning aptitude, which has been quantified by scores in paper-based tests. In this paper, we present our pilot study on a hypothesized association between foreign language learning and auditory evoked potentials (AEPs) to spoken words, with the aim of looking for a neurophysiological measurement of language learning aptitude. The AEPs to repeated Mandarin words, passively presented in multiple stimulus trains, were recorded from 18 native adult Mandarin speakers, by using a 32-channel EEG recording system. Their language learning performance was measured by their scores in a task of learning words in an African language, and by their achievements in standardized English tests. The results show that the short-term habituation induced by repeated Mandarin words could predict the participants' phonological learning performance, and is correlated with their scores in English tests. These findings suggest that AEPs to speak words can be a promising neural indicator to measure an individual's language learning aptitude, which may become an objective tool for human resource assessment.**

Keywords*—*Human resource; assessment; language learning; auditory evoked potential; globalization

I. Introduction

The language used in the workplace has diversified with business globalization. Although a lingua franca is usually promoted within one company as part of its language strategy, in recent years, there has been a rapidly growing demand for employees to learn a previously unknown language in want of success in works across countries [1-2]. However, it has been commonly aware that individuals differ from each other in their ability to master native languages, not to mention learn a new language. Therefore, how to screen for those who are better at learning a new language than other candidates, especially for job positions that require communication with a local language community, has imposed a great challenge for human resource assessment. The aim of this study is to bridge the gap between human resource management and cognitive neuroscience by proposing a potential, objective tool for measuring language learning gifts in adults.

In psychology, the gift for learning a language has been conceptualized as language learning aptitude (or language aptitude). Given the same amount of time in learning the same language materials, the more advanced learner can be considered to the one with higher language aptitude [3]. However, it cannot be denied that language learning is decided by multiple social and cognitive components. Therefore, the results of a paper-based aptitude test can be confounded by many factors that may not play a central role in determining an individual's language aptitude but only dominate one's performance in that specific test. As a result, an objective, reliable and valid tool is still required for distinguishing between more gifted and less gifted adult learners of a language.

Here, we reiterate our translation of language aptitude into a neurophysiological issue, by proposing that language aptitude is decided by the neural plasticity in language cortex [4]. Neural plasticity refers to the changes in neurons induced by sensory or motor input. That is to say, assuming that language learners undergo similar learning procedures, it is their biological basis that determines the results of learning driven by the neural plasticity in the cortical areas mapped with language functions.

To test this hypothesis, we chose auditory evoked potentials (AEPs) as the neural indicator for neural plasticity. The AEPs refer to the electoral potential components elicited by an auditory event, obtained from a continuous recording of

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electroencephalography (EEG) signals. More importantly, two cortical AEPs, P1 and N1, with latencies between 50 – 100 ms post-stimulus onset, are considered to be typical neurophysiological responses reflected obligatory response patterns to any auditory stimulation [5]. Recent studies identified that the P1 and N1 are not just indications of neural activities, but also sensitive to neurocognition at a cognitive level [6-7] and are even able to reflect neural plasticity induced by perceptual training [8].

Taking advantage of the correlation between neurophysiological indicator P1-N1 and cognitive activities, the present study aimed to investigate whether the P1-N1 complex elicited by natively spoken words in adult Mandarin speakers are associated with their language learning. Here, the scope of learning was defined within word-sound learning, as the AEPs are elicitable by using spoken words. Proficiency in foreign language learning was also considered. The reason is that the language aptitude is usually measured by the learning effect in a short period of time, whereas proficiency is a measure of the outcome after a longer period of learning.

II. METHOD

A. Participants

Eighteen participants took part in the experiment. All were native speakers of Mandarin Chinese and reported no hearing or language disorders, no left-handedness. They were randomly assigned to one of the two lists of test materials. Informed consent was given prior to the experiment.

B. Stimuli and experiment design

We aimed to observe the P1-N1 AEPs and their habituation in monosyllabic spoken words in Mandarin, that were either meaningful real words (RW) or meaningless pseudowords (PW). The lexicality was realized by pairing a segment template with a tone either in a lexical or a non-lexical way (e.g., /gei3/ (to give) vs. a pseudoword */gei1/). Ten words of each stimulus type were included and equally distributed in two lists. The recorder was a female, native Mandarin speaker. Stimuli were normalized for the same average intensity (65 dB) and duration (550 ms) using the acoustic software program PRAAT [10].

To elicit AEPs and their habituation, a short-term habituation design was used. A word-form was programmed to be presented in a stimulation train repeatedly for five times, noted as S1-S5, separated with a constant inter-stimulus interval (ISI) for 400 ms. Given an inter-train interval (ITI) for 4s, the electrophysiological response to a spoken word could be expected to recover from the perception of the previous train. Each train was presented 11 times. The materials in each list were divided into five blocks, each of which contains one type of word-forms from the four conditions. Such design allowed us to observe both the AEP responses in different types of spoken word stimuli and the changes of the AEP's amplitude and latency induced by the auditory habituation in the repeated stimuli in a train.

To quantify participant's language aptitude, the fifth part in Pimsleur Language Aptitude Battery (PLAB) was used [11]. PLAB is a reputable, standardized test on language aptitude, which has been widely used in middle-school students in the USA. Part IV of the PLAB was specialized in testing one's ability in discriminating segmental and prosodic contrasts in words from an African language. Their proficiency in a foreign language was measured by their scores of two standardized national English tests applied in almost all Chinese university students, namely College English Test Band 4 (CET4) and College English Test Band 6 (CET6).

C. Procedure

Each participant was asked to report their scores in CET4 and CET6 before the experiment. Then, participants were tested individually in a quiet room with constant, dim lightness, seated in front of a PC monitor. During the experiment, participants were instructed to watch an unsubtitled cartoon movie, and asked to remember the contents for a good performance in a comprehension test, administered after the EEG experiment. Moreover, they were encouraged to ignore any sounds, which were the stimuli, delivered binaurally via a pair of Sennheiser headphones, during watching the movie.

The EEG was recorded by a LiveAmp amplifier (Brain Products) via 32 Ag/AgCl electrodes situated on an elastic cap according to the extended international 10-20 system, with a 500 Hz sampling rate. One electrode was placed at the right infraorbital ridge to monitor the ocular movement. The online reference was Cz and the impedance of electrodes was kept below 5 kΩ.

After the EEG data collection, participants were asked to complete the aptitude test. During the test, a word-pair of di-syllabic words containing one phonetic contrast would be first introduced to a participant. Then, they were asked to judge which word is in a spoken sentence by choosing from the words just learned. This part consisted of three sections: segmental discrimination (item 1-7); prosodic discrimination (item 8-15); mixed discrimination of segment and prosody (item 16-30). A correct judgment of an item was scored as one point. Participants wrote down their answers on an answer sheet.

D. EEG data processing and analysis

EEG preprocessing was performed in Brain Vision Analyzer 2.0 (Brain Products). The EEG data were band-pass filtered between 1 and 30 Hz, and re-referenced to the average amplitudes recorded from the two mastoids. Voltage moves higher than 50 μv in a 200 ms time window were recognized as artifacts and rejected for further data analysis. Then, the EEG recording was segmented separately for the five presentations of each stimulus type, with an epoch of 600 ms, between −100 ms before and 500 ms after the stimulus onset. Baseline correction was performed by referring to the averaged amplitude in -100 to 0 ms. The peak amplitudes and peak latencies of the P1 and N1 were detected at three electrodes around the vertex, namely C3, Cz, and C4, placed from the left to the right scalp, in a time window between 50-80 for the P1 and 80-150 for the N1, for each type of stimuli at every presentation positions, for each participant.

Correlations with participants' scoring in the language aptitude test, and two standardized English exams were examined for four neurophysiological measures: peak-to-peak amplitude and inter-peak latency of the P1-N1 complex in S1, and the habituation of P1-N1 peak-to-peak amplitude, and inter-peak latency in repeated stimuli. The habituation in the amplitude was indexed by the habituation coefficient which was calculated by dividing the peak-to-peak amplitude in S1 with the averaged amplitude in S2-S5.

III. Results

Pearson correlation analyses revealed some correlations between the neurophysiological indicators recorded in different conditions at different electrodes and the participants' performance in learning a new language, and between these indicators and their foreign language proficiency (see Fig. 1 for four representative effects).

For the AEPs, the analysis only revealed a marginally significant negative correlation between the peak-to-peak amplitude of the N1-P1 to the real-word stimuli at C3 electrode and the score of mixed lexical learning task ($r(18) = -.458$, $p = .056$). The analysis with inter-peak latency identified a marginally significant correlation between the real-word at C3 and the CET6 scores ($r(18) = -.447$, $p = .063$). A tendency of a negative correlation between the real-word condition at C3 and the total scores of the aptitude test was found ($r(18) = -.397$, $p = .103$).

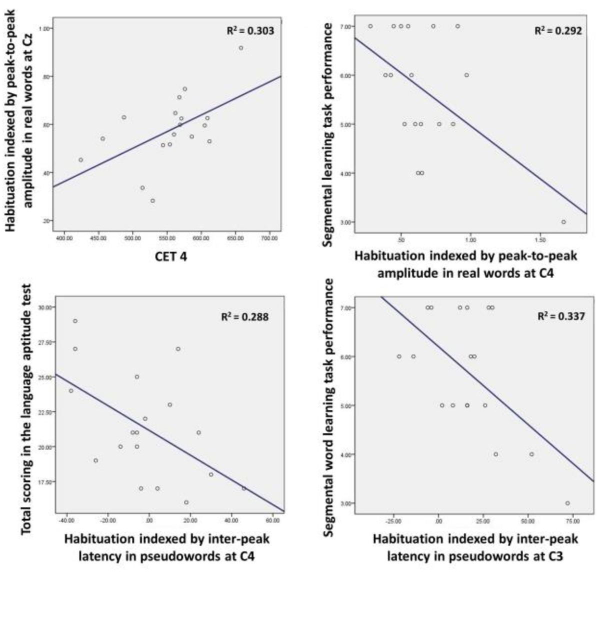

Fig. 1. Representative effects suggesting correlations between language learning and neurophysiological indicators

The analysis of auditory habituation in repeated stimuli revealed more evident correlations between the AEPs and language learning. The AEP habituation coefficients at Cz in the real-word condition ($r(18) = .551$, $p = .018$) were correlated with the scores of CET4. Moreover, the Cz in the real-word condition also exhibited a marginal significance correlation with the CET6 scores ($r(18) = .446$, $p = .064$). The AEP habituation coefficients at C4 in the real-word condition ($r(18) = -.540$, $p = .021$) were found significantly correlated with the scores of the segment learning task. For the same task, a marginally significant correlation with the habituation coefficients at C4 for the pseudoword condition was identified ($r(18) = -.442$, $p = .067$). A significant, negative correlation between the habituation coefficients at C4 for the pseudoword condition and the scores of prosodic learning task was found ($r(18) = -.477$, $p = .045$). In addition, the AEP habituation coefficients at C3 for the real-word condition were found correlated with the total score of the language aptitude test with a marginal significance ($r(18) = .447$, $p = .063$).

The latency changes in the auditory habituation were also found correlated with language learning performance. The changed latencies of the pseudoword condition at C4 were found negatively correlated with the total score of language aptitude test ($r(18) = -.537$, $p = .022$). Moreover, the changed latencies of the pseudoword condition at C3 were found negatively correlated with the score in the segment learning condition ($r(18) = -.581$, $p = .011$). In addition, a marginally significant correlation between the changed latencies in the real-word condition at C3 and scores of CET6 was found ($r(18) = 4.33$, $p = .073$).

IV. Discussion

The study reported is a pilot investigation on measuring the gift of learning a new language in adults with neurophysiological methods, in that the language aptitude could be hypothesized to be biologically determined by the neural plasticity of language cortices. For this purpose, the peak amplitudes and latencies of auditory P1-N1 complex were recorded in the first presentation of stimuli in a stimulation train (S1) and the following presentations, evoked by real words and pseudowords. Language aptitudes in various aspects of word sound learning and language proficiency were all collected.

The results show evidence that the habituation of the AEPs to repeated words is correlated with language learning, even though the S1 AEPs to a spoken word stimuli were not reliable indicators. These results may be caused that the habituation is more related to neuronal functionality, whereas the AEPs themselves only reflect common neural activities to auditory events. In detail, measured by amplitude, more persistent N1-P2 responses at C4 throughout the stimulus repetition may suggest greater language learning gift. This result may suggest the involvement of the right-hemisphere in the very early phase of phonological processing, in line with a previous study [6].

Furthermore, when the latency changes are considered, the P1-N1 in repeated pseudowords could become indicators for a better word learning and segment learning, as well. To be specific, better word learning performance is usually accompanied by speeded P1-N1 responses in repeated pseudowords relative to the responses to S1. This finding suggests the temporal feature of the neural network underlying language learning. Moreover, the total word learning performance and the segmental learning performance is related to the changed latencies at C4 and C3 electrodes. These results again may suggest an important role of the right hemisphere in word processing and learning [6], and are in line with previous studies finding that the phonological level processing of speech input (i.e., segments) is nested in the left-hemisphere (e.g., left perisylvian cortex and left pre-frontal cortex) [12].

V. CONCLUSION

To summarize, the current study shows that spoken-word elicited P1-N1 could be a potential neural indicator to evaluate the biological basis of language learning. In detail, the habituation as reflected by changes in the P1-N1 complex has an evident correlation with the proficiency in a foreign language (i.e., English), and could be predictors of one's achievement in learning the spoken words in a previously unknown language. These results support our hypothesis that language learning aptitude has a neurobiological basis. The findings in this study suggest a promising method to examine an individual's language learning gift with neurophysiological measures in adults.

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