International Journal of Social and Humanities Sciences Research
JSHSR
Uluslararası Sosyal ve Beşeri Bilimler Araştırma Dergisi
Uluslararası Hakemli Dergi- International Refereed Journal
ISSN: 2459-1149

Received / Makale Geliş Tarihi 08.01. 2024
Published / Yayınlanma Tarihi 29.02.2024
Volume / Issue (Cilt/Sayı)-ss/pp 11(104), 460-467

Research Article /Araştırma Makalesi
10.5281/zenodo.10737094

Assoc. Prof.Dr. Zeynep Zeliha Sonkaya
https://orcid.org/0000-0001-5307-1791
Ankara University, Faculty of Education, Ankara / TURKEY
ROR Id: https://ror.org/01wntqw50

How Adults Learn a Second Language: A Neurolinguistic Analysis of Brain Localization

Yetişkinlerde Yabancı Dil Öğrenimine İlişkin Nörodilbilimsel Bir İnceleme

ABSTRACT

The current study aims to investigate brain localization in the process of adult second language learning from an interdisciplinary point of view. It is believed that the knowledge of how the second language learning process works in the brain will contribute to lecturers studying second language teaching. This research was carried out on a sample of ten English-native speakers who underwent a six-month intensive Turkish as a second language program from initial exposure to high proficiency. A word task, a word/sentence-picture matching task, and a grammar violation task were used to evaluate the progress of language proficiency. In accordance with this purpose, the fMRI technique was used. Brain activity was observed in regions linked to the processing of the first language, including Broadmann Area (BA) 45/47. Additionally, activation was reported in the parietal cortex for lexical and semantic processing, and in BA44 and 6 for grammatical processing. These findings indicate that mature second language learners are able to utilize sections of the brain related to their first language. Additional areas were activated, indicating that first language mechanisms are insufficient for second language learning and processing. For both vocabulary and grammar, hippocampal activation was observed during the early phases of learning. Grammar-related basal ganglia activation was observed in the caudate nucleus during later phases. The findings suggest that the acquisition of vocabulary and grammar in the early stages is dependent on declarative memory, whereas the mastery of grammar in later stages is dependent on procedural memory. These results highlight the importance of integrating neural and behavioral methods in second language research.
Keywords: Adult second language learning, Turkish as a second language, Brain localization, fMRI, Neurolinguistics.

ÖZET

Bu disiplinler arası çalışmanın amacı ikinci dil öğrenen yetişkin bireylerin ikinci dil öğrenimi sürecine ilişkin somut verilere dayalı Nörodilbilimsel bir inceleme yapmaktır. Çalışma, Indiana Üniversitesi Turkish Flagship programında Türkçeyi yabancı dil olarak öğrenen başlangıç düzeyindeki 10 öğrenci üzerinde yürütülmüştür. 6 ay boyunca yoğun (intensive) Türkçe eğitim alan katılımcılara periyodik olarak seviye belirleme testi yapılmıştır. Hemen ardından katılımcılar uygulama odasına alınmış ve kelime, kelime/cümle-resim eşleştirme ve dilbilgisi testleri uygulanmıştır; eş zamanlı olarak da beyin görüntüleme tekniklerinden fMRI kaydı alınmıştır. Çalışma sonunda yabancı dil olarak Türkçe öğrenen bireylerde, kelime ve semantik bilgi işlemleme sürecinde pariatal korteks (BA 44), dilbilgisi işlemleme sürecinde ise frontal kortekste (BA 6) aktivasyon gözlenmiştir. Çalışmamızda yabancı dil olarak Türkçe öğrenen bireylerde, birinci dil öğreniminde etkin olan mekanizmaların ikinci dil öğrenme ve işlemleme sürecinde yeterli olmadığını düşündüren ek alanlarda belirgin aktivasyon artışı görülmüştür. Öğrenmenin erken aşamalarında hem kelime hem de gramer için hipokampal aktivasyon bulunmuş, daha sonraki aşamalarda ise özellikle de kaudat çekirdeğinde gramer için bazal ganglion aktivasyonu gözlenmiştir. Çalışmamızın bulguları, erken kelime ve dilbilgisi öğreniminin deklarasyon hafızaya dayalı olduğunu ancak daha sonraki dönemde dilbilgisi işlemleme sürecinde prosedürel belleğin devreye girdiğini göstermiştir. Yabancı dil olarak Türkçe öğretim sürecinde beynin ilgili alanlarını uyarıcı nitelikte eğitim programlarının hazırlanması, etkili ve kalıcı öğrenme açısından daha etkili sonuçlar verecektir.
Anahtar Kelimeler: Yetişkinlerde İkinci dil öğrenimi, Yabancı dil olarak Türkçe, Beyin Lokalizasyonu, fMRI, Nörodilbilim.

1. INTRODUCTION

Language plays a crucial role in our lives, not only in our mother tongue but also in other languages required for communication within the global community. Consequently, the significance of acquiring a second language (L2) has increased in recent times.

Acquiring proficiency in a foreign language necessitates the development of an intricate repertoire of linguistic abilities, such as encoding words, comprehending syntactic structure, and assimilating the resulting representations with pre-existing language knowledge. The process of acquiring a second language (L2) is particularly challenging in maturity, in contrast to the acquisition of a first language (L1) or the acquisition of an L2 by children (Tagarelli, 2014; Sonkaya and Bayazıt, 2018). Extensive research in the field of literature has focused on investigating alterations in behavioral performance that occur during the process of acquiring an L2 (Conklin & Pellicer-Sánchez, 2016; Orosco & Hoover, 2009; Roberts & Siyanova-Chanturia, 2013). However, there is limited understanding regarding the specific changes that take place in the brain as L2 learning progresses, the timing of these changes during the learning process, and how we can identify differences in brain changes that correspond to successful learning.

The research on second language (L2) acquisition in adults, as well as cognitive neuroscience, has made significant progress in understanding the process. Moreover, the presence of methodological restrictions has resulted in considerable gaps in the existing literature. From this perspective, the present study aims to investigate the process of adult second language learning, which cannot be comprehensively examined using solely behavioral methods.

In accordance with this purpose, we investigate the neurological processes linked to adult L2 acquisition by integrating behavioral analysis with fMRI, a non-invasive neuroimaging method that measures brain activity.

2. MATERIALS AND METHODS

2.1. Participants

This study was conducted on 10 healthy native speakers of English (5 female+ 5 male, mean age 24.47) between 18 and 30 years of age were trained in intensive Turkish as a second language class, from initial exposure to high proficiency. All participants were right handed. They were reported to have no history of neurological and psychiatric disorder, known hearing impairment, history of drug or alcohol abuse, long periods of unconsciousness and head injuries. The self-report screening was used to assess the exclusion criteria.

The participants were recruited by giving written consent form before the experiment. Prior to scheduling their participation, each steps of the experiment were explained verbally and also it was given the information about fMRI to ensure that they qualified for the study. Each participant had a study information sheet, which allowed them to be informed about the study. At any time, participants were permitted to withdraw from the investigation. The Ethics Committee granted approval for the experimental protocol (Protocol No: 2017/1712589128), and the present study was conducted in full adherence to the approved guidelines.

2.2. Stimuli

2.2.1. Turkish Picture Matching Task

Participants underwent training through a "forced-choice" Turkish picture-matching exercise, where they listened to a word or sentence and selected the picture that most accurately corresponded to what they heard (Figure 1 and Figure 2). Picture-matching tasks, which assess learners' knowledge of fundamental language associations between forms and meanings, are frequently implemented in both foreign language classrooms and research on language acquisition (Yang et al. 2015).

During the picture-matching task, participants were presented with an auditory stimulus in the form of a word or sentence. Following a 250 ms period of focusing on a cross, two photographs were displayed. One of the images, referred to as the "target," corresponded to the given phrase or sentence, while the other image, known as the "foil," did not. Participants were directed to select the image that corresponded to the auditory stimulus by pressing a button, triggering the appearance of an asterisk on the screen. After a fixed amount of time (2000 ms for words and 3500 ms for sentences, based on pilot testing), the wrong picture disappeared, and the true picture remained on the screen for 1000 ms, ensuring feedback intended to promote learning. Ten sentence-level picture-matching runs were generated for the training and retention sessions of this investigation. The location of targets (left/right) was pseudorandomized and counterbalanced. Two versions of each task were created so that the placement of targets and foils in one version was the opposite of their placement in the other.

The test was took place in two parts: Turkish-Word Picture Matching Test and Turkish Sentence-Picture Matching Test.

Turkish Word- Picture Matching Test: The test consisted of 12 tangible content (open-class) words, all of which are often in both Turkish and their English translations: 4 nouns (animals), 4 verbs (transitive), and 4 adjectives (colors). Images were drawn taking an example by Snodgrass and Vanderwarts' (1980) standardized set of pictures (Snodgrass and Vanderwarts, 1980) and modified to stand for all words and sentences in Turkish using Adobe Photoshop.

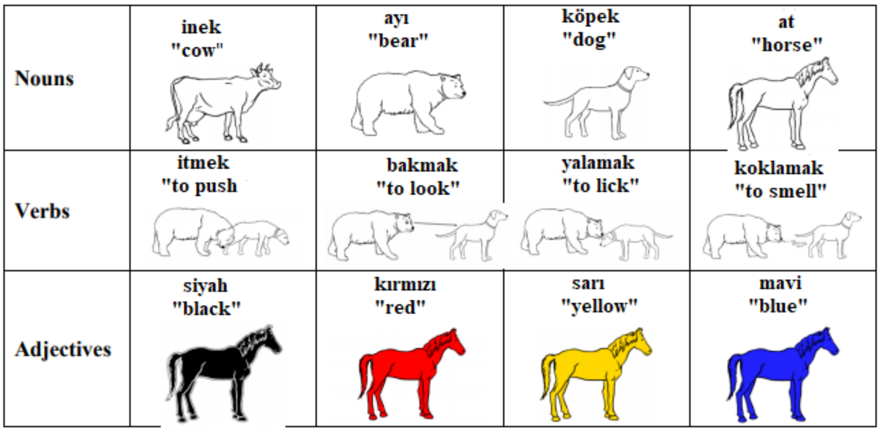

Figure 1. Sample images for Turkish Word-Picture Matching Test.

In the word-level picture-matching task, the target and obstacle consistently belonged to the same word class, specifically verbs, adjectives, or nouns. The pairs were minimal, demonstrating a modification along a single dimension. For example, while referring to the word "ayı," which means "bear" in English, the participant may be shown an image depicting both a bear and a horse, but both images would be of the same color. Regarding the word "mavi," which is equivalent to "blue" in English, the participant may observe a picture of a blue cow and an image of a red cow, but never two distinct animals.

Turkish Sentence-Picture Matching Task: In the task of matching pictures at the sentence level, both the targets and distracters were minimal pairs. During this test, the target image serves as a representation of the text, while the distracters deviate from the sentence merely in terms of word order, one dimension, either lexicon or agreement. Specifically, the distracters in question either portrayed a noun that did not correspond in quantity to the sentence, whether as the subject or object (Figure 2b), exhibited an incorrect lexical position (Figure 2c), or displayed the agent and patient of the sentence in inverted roles (Figure 2d).

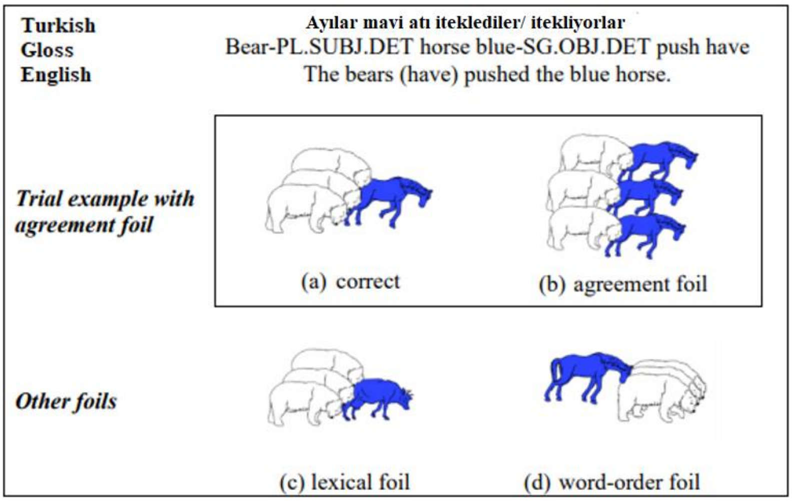

Figure 2. Illustrative images for the Turkish Sentence-Picture Matching Test. During the test, the individual would be presented with a Turkish text and shown both the correct image and one of three distracter images, depending on the condition.

The aim of these three conditions was to measure lexical/semantic, syntactic, and morphosyntactic learning separately.

2.2.2. Auditory stimuli

A total of 12 word sound files (one per word) and 888 sentence sound files (744 grammatical, 144 ungrammatical) were produced for this study. All words that comprised content word roots, singular and plural forms of nouns and adjectives, and function words and a subset of sentences were recorded by a male native Turkish speaker. The subset of recorded sentences consisted of 80 grammatical sentences, which included two iterations of every noun phrase in both the subject and object position, for example "kırmızı ayı" which translated the "red bear", and at least two reiterations of every verb/auxiliary pair, for example for "push": iteledi, iteliyor, iteler ve iteleyecek. Additionally, a total of 35 sentences with grammatical errors were documented. These 35 sentences included two versions of each incorrect noun phrase or verb/auxiliary combination found in the list of 144 ungrammatical sentences. Each sentence was duplicated and analyzed separately. The most favorable recording of each noun phrase (selected independently for subjects and objects) and verb/auxiliary combination was extracted, with minimal pauses at the beginning and end of each segment. The length of pauses between each phrase in the naturally occurring speech was also measured. The duration of the pause between the subject noun phrase and the object noun phrase was slightly decreased in order to decrease the average sentence length. Additionally, the duration of the pause between the object noun phrase and the verb phrase was slightly increased to ensure a clear distinction between these phrases in spoken language.

2.2.3. Turkish Word and Sentence Production Task

The Turkish word and sentence production task was a simple picture-naming task at the word level and a scene description task at the sentence level. In word-level production, participants saw a picture depicting a noun, verb, or adjective, and were asked to name what they saw (Figures 3a and 3b).

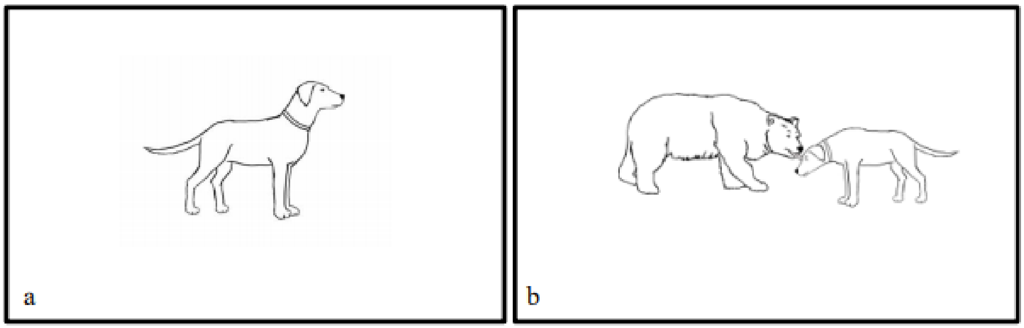

Figure 3. Example of Turkish Word and Sentence Production Task: a) word level b) sentences level

For example, if the participant saw the image in Figure 3a, he or she should say "köpek", which means "dog" in English, out loud. In sentence-level production, participants saw an image depicting a scene that could be described using the vocabulary and grammar they previously learned. They were asked to produce a sentence describing the image, and to say as much about the image as they could. For instance, if the participant saw the image in Figure 3b, he or she should say "Ayı köpeği yaladı" which is translated as "The bear licked the dog" in English. No feedback was ensured during production. In the literature, various studies showed that learners were able to do such tasks after a short training period (Grey, 2013; Hudson Kam & Newport, 2009; Tagarelli, 2014). A total of 4 production runs for each level (word and sentence) were created for the training and retention sessions of this experiment. Each run included 24 trials. For words, each word was presented twice per run. For sentences, each singular/plural-subject/object combination was presented six times, and other features of the sentences (animals, colors, verbs) were balanced.

2.3. Procedure

The entire study consisted of five sessions on separate days, lasting from about 1.5 to 2.5 hours each. Participants were recorded by using fMRI while performing the Turkish Picture Matching Task and Turkish Word and Sentence Production Task. On the first day, the participants engaged in a brief practice session where they acquired the skills to perform control tasks, word-picture matching tasks, and sentence-picture matching tasks using English stimuli. This included four control items for practice, along with three illustrative items, three exemplar items, and 12 practice items for both words and phrases. These items were evenly dispersed across different word classes and conditions. Practice lasted about ten minutes. After practice, participants completed four word-level picture-matching tasks. In the scanner, subjects completed one more word-level picture-matching, two sentence-level picture-matching and two grammar-level production tasks. Afterward, they completed the word and sentence production tasks outside of the scanner. The second language training session was scheduled about two days after the first day.In this session, participants completed a short practice task with the same practice items as on the first day, but without examples and sample items. They then completed two word-level picture-matching tasks. In the scanner, participants completed four sentence-level picture-matching runs. They completed the word and sentence production tasks outside of the scanner. The third and final language training session was scheduled about two days after the second day. In this session, participants completed the exact same practice task as on the second day, followed by two word level picture-matching runs. In the scanner, they completed one word-level picture-matching run, two sentence-level picture-matching runs, and two grammar violation tasks. Once again, they completed the word and sentence production tasks outside of the scanner. All participants returned for a follow-up session about one month after the final training session. This session was identical to the third language training session, except that the versions of the tasks were different.

fMRI analyses were completed using the SPM8 software package (http://www.fil.ion. ucl.ac.uk/spm/software/spm8/) for MATLAB (The Mathworks, MA). Before pre-processing, all EPI images were manually reoriented to align with the SPM T1 weighted template image. Pre-processing included slice timing correction, which temporally corrected EPI images to the middle slice, spatial realignment for motion correction, coregistration of EPI scans to structural scans, segmentation of MP-RAGE volume by tissue type, spatial normalization to a standard MNI reference brain with a voxel size of 2mm3, and smoothing with a Gaussian kernel of 6mm full width half-maximum (FWHM).

For all reported fMRI results, anatomical locations were determined using MRIcron (http://www.mccauslandcenter.sc.edu/mricro/mricron/), and brain areas were determined using the SPM Anatomy Toolbox (Eickhoff et al., 2005). However, it should be noted that brain areas are approximate, as it is impossible to determine the cytoarchitectonics of cortical regions from fMRI data.

$p < .05$ the statistical threshold value was accepted significant, with a family-wise error (FWE) correction for multiple comparisons.

3. RESULTS

Word level- picture matching task. Each participant underwent 10 iterations of the word-level picture matching task during a three-day training period. A repeated measures ANOVA with a 10 x 3 design was conducted, using Run and Condition as within-subjects components. The study revealed a notable increase in accuracy for adjectives compared to verbs.

When both word-level picture-matching runs were collapsed, ROI analyses revealed significant activation in right BA45, $t(13) = 2.368$, $p = .042$, and a trend toward significant activation in right BA44, $t(13) = 1.899$, $p = .058$. There was significant deactivation in the right putamen, $t(13) = -2.628$, $p = .045$. The same pattern of activation and deactivation was apparent when Day 3 was analyzed separately, but no regions were significant (Right BA45: $p = .089$; Right BA44: $p = .086$; Right putamen: $p = .098$). On Day 1, the right hippocampus was activated, but not significantly, $t(13) = 1.675$, $p = .073$. Left BA44, $t(13) = -3.103$, $p = .06$, and left BA6, $t(13) = -2.568$, $p = .044$, were significantly deactivated, and left BA45, $t(13) = 1.952$, $p = .089$, and right BA6, $t(13) = -1.697$, $p = .092$, were also deactivated, but not significantly. There was a significant increase in percent signal change from Day 1 to Day 3 in left BA44, $t(13) = 3.554$, $p = .002$, and left BA6, $t(13) = 2.522$, $p = .040$, but no significant decreases.

At the word-level, only a single voxel in one contrast was significant. On Day 3, words activated a voxel adjacent to the right posterior hippocampus (42, -38, 0) when contrasted with baseline.

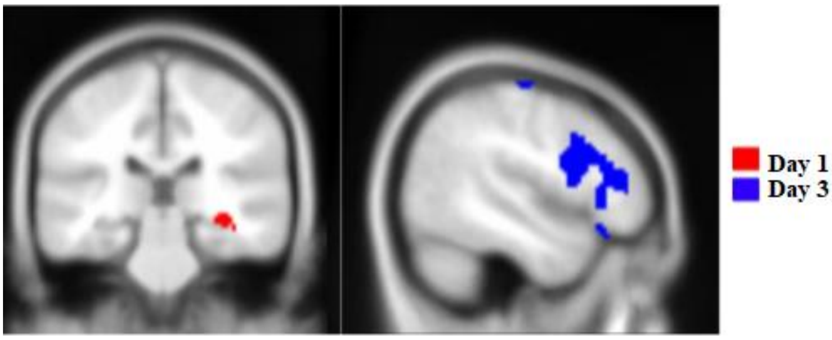

Figure 4. ROI analysis revealed word-level activity in the right hippocampus on Day 1 and in the left inferior frontal gyrus on Day 3. The photos display the outcomes of a correction applied to a limited volume, encompassing all 16 regions of interest, with a significance level of $p < .05$.

Sentence level-picture matching task. Subjects completed 8 runs of the sentence-level picture matching task over the course of three training days. The fMRI data show that during the sentence level-picture matching test, there was activation in the right BA 44 and both sides of BA 45. Deactivation was observed in the right caudate, bilateral BA47, bilateral hippocampus and parahippocampal gyrus, and bilateral putamen. Activation was observed in the bilateral BA44, left BA47, bilateral BA45, and bilateral putamen when comparing the feedback condition to the baseline condition. Deactivation was observed in both the bilateral hippocampus and parahippocampal gyrus.

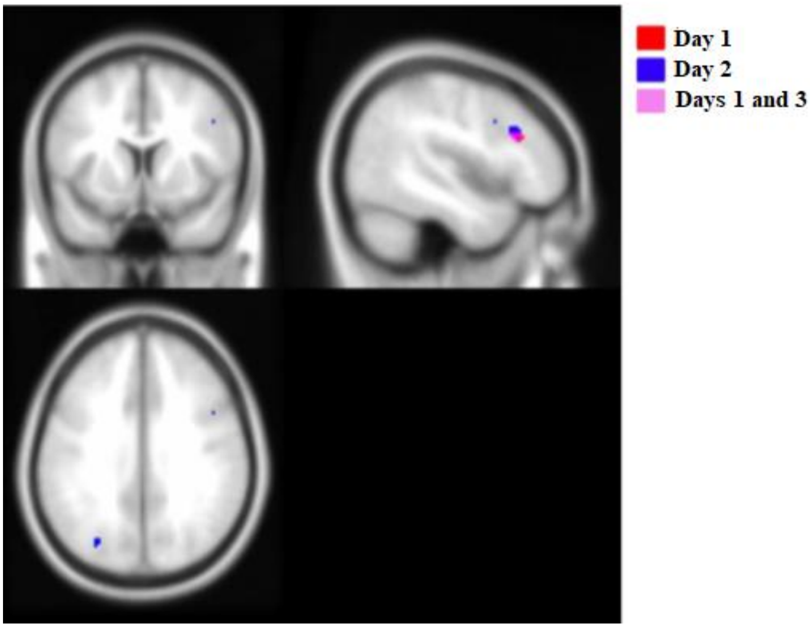

Figure 5. Sentence-level activation in the brain analysis.

Word and Sentence Production Task. A repeated measures ANOVA demonstrated a significant effect of Day, $F(2, 24) = 34.650$, $p < .001$. Bonferroni corrected post hoc comparisons showed that performance increased significantly between each day ($p < .005$). The repeated measures ANOVA indicated a significant impact of Day, with $F(2, 28) = 51.974$, $p < .001$, partial $\eta 2 = .788$, and observed power = 1.0. Bonferroni corrected post hoc comparisons revealed a substantial increase in performance between each consecutive day ($p< .001$).

4. DISCUSSION

Our study uncovered that the brains of adult second-language learners exhibit remarkably dynamic activation, even in the initial phases of the L2 learning process. Brain activation was observed in the Broca and Wernicke areas, which are related to the L1. Further regions were involved, indicating that L1 processes alone are inadequate for L2 acquisition and processing. Hippocampal activation was observed in the initial phases of language acquisition, encompassing both vocabulary and grammar. Subsequent to that, there was a reported activation of the basal ganglia, specifically in the caudate nucleus, in relation to grammar. In a similar vein to the current work, Hirsch et al (2000) conducted research at Cornell University utilizing fMRI to ascertain the manner in which the human brain represents various languages.

Researchers discovered that there is a distinct spatial separation between native and second languages within Broca's area. This area, located in the frontal lobe of the brain, is responsible for the motor aspects of language, such as the movement of the mouth, tongue, and palate (Hirsch et al., 2000). In another study conducted by Wang et al (2013), it was shown that there was minimal differentiation in the activation of Wernicke's area, a region in the posterior section of the temporal lobe that plays a role in language comprehension when two languages were compared using fMRI (Wang et al., 2013).

Our findings also indicated that there was no substantial brain activation observed during the word acquisition process on Day 1. Nevertheless, notable patterns surfaced in relation to the activation observed during the word acquisition challenge. Marginally significant activation was observed in the bilateral hippocampus on Day 1, while considerable activation was detected in the right parahippocampal gyrus on Day 3. Furthermore, there was observed deactivation in certain regions of the inferior frontal gyrus, including BA44, BA45, and BA6, although the latter was not statistically significant. Notably, there was a tendency for BA44 and BA45 to become more active on Day 3, indicating a change in the role of these regions as learning advanced. To summarize, although the significance is minimal, there was activity observed in the right putamen only on Day 3. During the process of phrase learning, only the right BA45 region of the brain was active on Day 1, whereas the right prefrontal cortex (BA9) was deactivated. On the third day, activation in the right Brodmann area 45 was sustained but also expanded to include the right Brodmann areas 44 and 6. This discovery is particularly intriguing since it demonstrates a rise in activation of the inferior frontal gyrus during the process of learning. Specifically, BA45 is involved in the first stages of learning, whereas BA44 and BA6 are recruited in the later stages of learning.

The fMRI scans of the Turkish learners revealed activity in neocortical regions that are normally involved in processing their L1, such as the inferior parietal lobe and the left inferior frontal gyrus, specifically BA 44 and BA47 for lexical and semantic processing, and BA 44 and BA6 for grammatical processing. The activation of these regions in Turkish learners indicates that many of the areas involved in the processing of an early-acquired L1 are still accessible and utilized by late L2 learners. In other words, as individuals age and acquire a new language, they do not entirely lose the brain mechanisms that make up their L1. Despite this convergence, it remains uncertain if L2 learners employ these mechanisms in a manner identical to that of L1 speakers.

Furthermore, the Turkish learners exhibited activation in brain regions outside those generally involved in processing their L1. This indicates that although the L1 language areas were active, they alone are inadequate for learning and processing an L2. Initially, activation was observed in regions believed to be associated with learning and memory consolidation, such as the basal ganglia, hippocampus, mediotemporal lobe, and potentially the middle occipital lobe. It is logical that these brain regions would be involved in an L2 learning paradigm, but not in L1 because L1 processing studies often involve adults who have already acquired their language. (Skeide, Brauer, & Friederici, 2014). Second, although L1 activation is typically found in the left hemisphere, Turkish learners showed more extensive and bilateral activation, and actually demonstrated right hemisphere dominance for many structures. In the literature, many studies demonstrated greater activation in L2 relative to L1 is likely due to the increased effort involved in learning and processing an L2 (Abutalebi, 2008; Skeide et al., 2014; Tagarelli, 2014), but the reason for right hemisphere dominance is still unclear.

In conclusion, the findings derived from neuroimaging studies, such as the one mentioned, can contribute to addressing the challenge of defining and measuring proficiency in a precise and practical manner. Recent neuroimaging research has demonstrated that relying solely on behavioral evidence may not be adequate for assessing competency, as distinct groups of speakers can exhibit equal performance on language tests while displaying distinct brain patterns (Tagarelli, 2014). The study reveals that learners with low behavioral performance in L2 tasks employ distinct structures during the learning process compared to high-performing learners. Specifically, when it comes to grammar, individuals with lower proficiency demonstrate a stronger dependence on structures associated with declarative memory, such as the mediotemporal lobe and hippocampus. On the other hand, individuals with higher proficiency exhibit a transition towards structures linked to procedural memory and implicit processes, such as the basal ganglia, BA44, and BA6. This implies that a highly skilled learner's profile may extend beyond excelling in behavioral tasks and includes the activation of certain brain areas that indicate the capacity to automate grammar. The objective of L2 instruction, therefore, may not solely be to enhance performance on language assessments but also to ascertain the specific training conditions and cognitive capacities that can promote the engagement of these innate processes in the brain.

5. CONCLUSION

The findings suggest that the acquisition of vocabulary and grammar in the early stages is dependent on declarative memory, whereas the mastery of grammar in later stages is dependent on procedural memory. These findings provide insights into neurocognitive theories of second language acquisition, and underscore the need to combine brain and behavioral approaches in L2 studies.

Acknowledgement. I would like to thank Professor Xiong Jiang for his supervisor to analyzing fMRI data and Professor Sharlane Newmann for her help with study administration.

REFERENCES

Abutalebi, J. (2008). Neural aspects of second language representation and language control. *Acta psychologica, 128*(3), 466-478.

Conklin, K., & Pellicer-Sánchez, A. (2016). Using eye-tracking in applied linguistics and second language research. *Second Language Research*, *32*(3), 453-467.

Eickhoff, S. B., Stephan, K. E., Mohlberg, H., Grefkes, C., Fink, G. R., Amunts, K., & Zilles, K. (2005). A new SPM toolbox for combining probabilistic cytoarchitectonic maps and functional imaging data. *Neuroimage, 25*(4), 1325-1335.

Grey, S. E. (2013). *A neurocognitive investigation of bilingual advantages at additional language learning.* (Phd Dissertation). Georgetown University,

Hirsch, J.,Ruge M., Kim, K., Correa, D.,Victor, J.,Relkin, N., Labar, D., Krol, G., Bilsky, M., Souweidane, M., DeAngelis, L., Gutin, P. (2000). An integrated functional magnetic resonance imaging procedure for preoperative mapping of cortical areas associated with tactile, motor, language, and visual functions. *Journal of Neurosurgery, 47*(3), 711-722.

Hudson Kam, C. L., & Newport, E. L. (2009). Getting it right by getting it wrong: When learners change languages. *Journal of Cognitive psychology*, *59*(1), 30-66.

Orosco, M., & Hoover, J. (2009). *Characteristics of Second Language Acquisition, Cultural Diversity, and Learning/Behavior Disabilities.* Paper presented at the Differentiating learning differences from disabilities: Meeting diverse needs through multi-tiered response to intervention.

Roberts, L., & Siyanova-Chanturia, A. (2013). Using eye-tracking to investigate topics in L2 acquisition and L2 processing. *Studies in Second Language Acquisition*, *35*(2), 213-235.

Skeide, M. A., Brauer, J., & Friederici, A. D. (2014). Syntax gradually segregates from semantics in the developing brain. *Neuroimage, 100*, 106-111.

Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of experimental psychology: Human learning and memory*, *6*(2), 174.

Sonkaya, A. R., & Bayazıt, Z. Z. (2018). A neurolinguistic investigation of emotional prosody and verbal components of speech. *NeuroQuantology*, *16*(12), 50.

Tagarelli, K. M. (2014). *The neurocognition of adult second language learning: An fMRI study*. (PhD Dissertation). Georgetown University,

Wang, L., Chen, D., Yang, X., Olson, J. J., Gopinath, K., Fan, T., & Mao, H. (2013). Group independent component analysis and functional MRI examination of changes in language areas associated with brain tumors at different locations. *PloS one*, *8*(3), e59657.

Yang, J., Gates, K. M., Molenaar, P., & Li, P. (2015). Neural changes underlying successful second language word learning: An fMRI study. *Journal of Neurolinguistics*, *33*, 29-49.