

A Review of the Critical Period Hypothesis in Second Language Acquisition

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Abstract

The issue about the Critical Period Hypothesis in the first and second language acquisition has been on dispute since the notion of the critical period in biology was proposed. In this paper, We make a review of the studies supporting and opposing the existence of a critical period in second language acquisition from the perspectives of psycholinguistics, cognitive linguistics and neurolinguistics in different language aspects. We concluded that no consensus on this controversial issue was found, because of the different research methods, materials, participants in different studies and the discrepant measurement standards and understanding of scholars about the critical period in language acquisition. We also suggested significant implications of the research findings for second language teaching, and made some recommendations for the future research on age effect upon second language acquisition in China.

Keywords: Critical Period Hypothesis; second language acquisition; age effect

1. Introduction

Originally, the concept of the “critical period” derives from biology. It refers to a period of time in the lifespan or development of an organism, in which the environment plays the vital and optimal role for the individual to learn a kind of behavior. During the critical period and under the effect of the appropriate environment, the acquisition of certain behaviors happens rapidly and efficiently, and the organism is extremely sensitive to the environmental stimuli. This kind of developing phenomena and laws were first discovered in 1935. In 1935, Konrad Lorenz, an Austrian zoologist and ethologist, through observing the phenomenon that a graylag goose only became attached to a parent figure within the first 36 hours after being hatched, he named any type of rapid learning as “imprinting” which occurred in a particular life stage without the necessity of reinforcement management. He also claimed that imprinting merely appeared in a short “critical period”.

Penfield and Robert (1959) firstly introduced the concept of the “critical period” into first language acquisition, and proposed the notion of “the Optimum Age” of acquiring a language. They found that the language-acquisition competence of children was closely related to the cerebral development; and the optimal age for language acquisition kept until 10 years old. The brain remains plastic during this period of time, but along with the arrival of puberty, this kind of plasticity gradually disappears due to the lateralization of language function in the left cerebral hemisphere. Lenneberg (1967), a German linguist and neurologist, published the book *Biological Foundations of Language*, developing and popularizing the “Critical Period Hypothesis”. Lenneberg's critical period hypothesis stated that there were physiological constraints at the time a first language could be acquired. After 2 years old and before the puberty (generally speaking 10 to 12 years old), both hemispheres of children's brains are involved in language acquisition; therefore language comprehension and production is much easier. However, after the puberty age, the lateralization happens, the cerebral maturational process is accomplished and the neuroplasticity is lost. Because of that, the natural and automatic nature of language acquisition declines and it becomes increasingly more difficult to acquire a language. Briefly speaking, if language acquisition does not occur by puberty, children's language acquisition ability is constrained. Despite of the fact that some aspects of language can be learned, full mastery of them is scarcely impossible. Through the study of children language disorder, Lenneberg (1967) further clarified and strengthened the “Critical Period Hypothesis”.

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He investigated brain injured children's language ability and language acquisition and found that young children with severe brain injuries still could acquire a language normally; only after a certain age around puberty, the brain damage would really exert negative influence on language acquisition and even cause aphasia.

Chomsky, the famous American linguist, also propounded the relevant theory about Children's first language acquisition, namely generative linguistics aiming at revealing why children could in just a few years successfully acquire their first languages which are so complicated. He proposed that there was a Language Acquisition Device (LAD), an innate facility, inherited in the human brain to acquire language. It suggested that people were innately equipped with the language acquisition competence (Chomsky, 1965). In the meanwhile, Chomsky also argued for the poverty of the stimulus as an evidence corroborating the existence of LAD (Chomsky, 1980). Many empiricists believe that people learn language from experience and that the exposure to abundant and adequate stimuli of a certain language is indispensable for successful language acquisition. Nevertheless, in fact, nobody can truly ensure that children are able to receive sufficient inputs to acquire every rule of a language in a linguistic environment during such a short time, only if they approve of the function of LAD. It is this LAD that allows the children to naturally and quickly acquire the intact rules of their first language and the whole language competence once they are exposed to a certain language environment. Nevertheless, the LAD has an active period, that is, when human beings are about 3 years old. It can explain why people of different races and languages always master their own mother languages almost at the same age. In terms of the biological nature of language, Chomsky's LAD theory is consistent with Lenneberg's Critical Period Hypothesis.

As has been mentioned, the Critical Period Hypothesis was rendered primarily to explain the acquisition laws of the first language. The observation and research on many social cases and phenomena has proved the rationality of the critical period as for the first language acquisition, such as the case of wolf children discovered in Calcutta, India in 1920 and studies of feral and isolated children (Lane, 1976; Curtiss, 1977; Friedmann and Rusou, 2015). Beyond that, the concept of the "critical period" has aroused interest in the research field of second language acquisition. A large number of scholars have debated and conducted numerous behavioral, psychological and cognitive neurolinguistic studies on the issue whether there exists a critical period in second language acquisition. For example, the symposium edited by David Birdsong (1999), *Second Language Acquisition and the Critical Period Hypothesis* assembled the empirical studies on Critical period Hypothesis from various perspectives, based on different research methods and with focuses on distinctive language aspects. The findings of these explorations concerned our understanding about how language knowledge was organized in human brain and also influenced significantly the strategic choices of language teaching methods and policies. However, different studies received different findings, so there is not yet a consolidated final conclusion about this question. In this paper, we conducted a brief review on the classic, famous studies and the latest research development on the critical period in second language acquisition.

1. Studies Supporting Critical Period Hypothesis in SLA

According to the Critical Period Hypothesis in first language acquisition, there should also be three hypotheses about the relationship between the age of acquisition (AoA) of L2 and the L2 ultimate attainment in second language acquisition: (1) During the critical period, there is a salient negative correlation between the L2 AoA and L2 learning efficiency. In other words, the younger the starting age is, the better their L2 learning performance will become; the older the starting age is, the worse their L2 learning performance will become. (2) When the starting age exceeds the critical period, those late learners' language acquisition competence experience an abrupt decline and no further significant relationship will be observed between the age and the achievement. (3) The final L2 achievement level of the late learners beyond the critical period will not reach that of the corresponding native speakers.

Many studies have provided some psychological, cognitive behavioral and neurolinguistic evidence to support these hypothesis. Oyama (1976) investigated 60 Italians immigrants to the United States. They arrived at the United States between the ages of 6 and 20, and had been living there for 5 to 18 years. The study showed that only the people who arrived before the age of 12 spoke with accents more resembling Americans' ones, but the length of residence in the United States had little effect on accent development.

Johnson and Newport (1989)'s and Johnson (1992)'s studies are renowned as the landmark and the most authoritative ones in the related field. Johnson and Newport (1989) offered an English grammar judging task to the 46 immigrants in the USA with Chinese or Korean as their first languages, who settled down in the USA at different ages ranging from 3 to 39 and had staying there for over 5 years, in order to find out the relationship between the settling age and the test performance. They also tested the 23 native English speakers as the comparing group.

The results demonstrated that the performance of the participants with arrival ages before 7 had no significant difference with that of native speakers. By the contrary, there was an obvious decrease in the performance with the increase of the arrival age among the participants who arrived between 7 and 16. Moreover, the results of the participants with arrival ages ranging from 17 to 39 showed no correlation between the age and their grammar judging performance. Johnson (1992) replicated this study in a writing task and found similar outcomes.

Weber-Fox and Neville (1996) utilized a method combining behaviorism and electrophysiology to examine if the L2 AoA had constraints upon L2 processing and how. They required Chinese English learners to self-report their L2 level and assessed their grammatical skills. They compared the behavioral data and the ERP data got in the tests and the results presented a plummet of the L2 learning ability of adults with the increment of age. The later the learners started to study L2, the slower their semantic processing was. With the growth of the starting age, the degree of specialization of the left hemisphere was increasingly weakened, while that of the right hemisphere involved in syntactic processing was strengthened. Furthermore, they also found that in the aspect of learning the open word class and the close word class, there was significant difference in distribution in the nervous system in accordance to different starting ages and that the data of late L2 learners manifested slower learning speed in learning open words. Meanwhile, many studies (Kim, et al., 1997; Wartenburger, et al., 2003) using fMRI to investigate the influence of the L2 AoA on the cerebral cortex activity demonstrated that there was no significant difference in the brain activity of earlier L2 learners (before 6) between L1 and L2 processing, but as for later L2 learners, L1 and L2 processing respectively activated different cerebral areas. Hence, the L2 AoA indeed affected the brain activity.

It is also worth mentioning that a large-scale investigation was conducted by Abrahamson and Hyltenstam (2009) on whether L2 learners could truly achieve an ultimate attainment level close to that of native speakers. Abrahamson and Hyltenstam examined 195 native speakers of Spanish and Swedish whose starting age to learn L2 ranged from 1 to 49 but all believing that their L2 level was equivalent to that of native speakers. This investigation contains a series of language activities, including the phonetic pronunciation and perception, word and sentence perception, written and auditory grammar judgment, integrated gap filling, idioms and proverbs usage and so on. Thus, it was a relatively comprehensive measurement of the true proficiency degree of the participants' second language. The experimental findings demonstrated that in terms of listening skills, as for the participants who started to learn L2 after 12, only a few had reached the native level, while a majority of those with beginning age before 12 managed it. Nonetheless, only several ones among the 41 participants who reached the native speaker level in listening tests were capable of reproducing this achievement in all the complicated and more difficult tests. Therefore, Abrahamson and Hyltenstam concluded that it was almost impossible for people who took up L2 after the adult age to fully attain the native like proficiency of L2.

More recently, the Critical Period Hypothesis in SLA has gained more empirical support in China and abroad. Xin and Zhou (2006) conducted a survey designed to discover the relationship between the L2 (English) proficiency level of non-English-major graduates in a university of China and the English curriculum setting condition in the primary school period. According to the statistical results, whether a student started studying English in the primary school or not had no significant influence on the English performance of those graduates whose English achievements were of low and medium level. Despite that, English learning experience in the primary school played a vital role for those graduates with relatively better or best English performance. The graduates who began English learning in the primary school accounted for most proportions in those who learned English best. Therefore, they considered it as reasonable that if children started to learn English at the third, fourth or fifth grade (at about 9 years old) in the primary school, they were much more likely to obtain a relatively higher English level in their adult or graduate period. Ma (2012) implemented a questionnaire survey and interviews to students in ethnic minority areas in China to investigate their ages of starting English learning, their College English Test achievements and their attitudes towards learning L2 at a younger age. It was found that students with a younger English AoA tended to perform better in the CET 4, suggesting that the L2 AoA importantly influence students L2 achievement in the future. At the same time, those students of ethnic minorities (the Tibetan nationality and the Uighur nationality) themselves felt that early exposure to English not only benefited the English learning in the future, but also could refrain from disturbing the acquisition of Chinese. However, we have to admit that Xin and Zhou (2006) and Ma (2012) did not control the L2 learning time of students, so perhaps it was because those who started L2 learning at a younger age had studied L2 for a much longer time that they performed better among the peers in the future. Dirix and Duyck (2017) probed into the L1 and L2 AoA effects in a combined eye tracking and corpus study method. They found that the L2 AoA effect had an influence throughout the entire L2 reading process, analogous to the L1 AoA effect. Besides, the interesting fact was that if the L1 translation of the L2 word was learned earlier, the L2 word was also read faster.

These studies have provided relatively strong psycholinguistic and cognitive neuroscience proofs from different perspectives of a second language to the Critical Period Hypothesis in SLA. Nevertheless, outcomes of many other empirical studies refute the idea of the existence of a critical period in second language acquisition and at the same time, many other second language acquisition models and theories have been proposed and proved as valid in one way or another.

2. Studies Rejecting Critical Period Hypothesis in SLA

Snow and Hoefnagel-Hohle (1978)'s longitudinal research observed the acquisition of Dutch as L2 of English native speakers at different ages in the natural language environment. It manifested that in the first few months, adult participants as well as those of the 12-15 group learned the fastest, but one year later, the 8-10 and 12-15 groups mastered Dutch best while the children who began to learn Dutch at 3 to 5 years old were the lowest performing team. It could be seen that these result negated the existence of a critical period in the second language acquisition for their incongruence with the hypothesis about the relationship between AoA and the L2 learning performance. Snow and Hoefnagel-Hohle believed their research results tended to support the viewpoints that the brain had been fully developed with the cerebral lateralization completed early before puberty or even before 3 to 5 years old and that the functional asymmetry was an innate nature in the human brain structure.

The Critical Period Hypothesis is widely criticized by scholars usually due to its over-generalization about language acquisition in all respects of a language and its insistence on the abruptness of the retrogression of language learning ability once beyond the critical period. It in essence holds a simplified, uni-module view about the actually complicated language acquisition process and accordingly, the critical period is the factor dominating the "sudden" qualitative change of language competence development. Opposed to this, many scholars like Long (1990, 2005), Dekeyser, et al.(2010) and so on propounded and advocated the Multiple Critical Period Hypothesis (MCPH) and the Multiple Sensitive Period Hypothesis (MSPH). MCPH inherits the view that there exists salient critical starting and ending points of the rapid improvement of language acquisition, but it argues that language acquisition involves various language modules such as phonetics, vocabulary and grammar. Different modules possess their own distinctive critical periods. Long (1990) discovered that children's competence of phonological acquisition would decrease after 6, but that of vocabulary and grammar could lasted until they were 15, indicating disparate patterns of how the critical period functioned in different language respects. Further, aside from supporting the multi-module view, MSPH directly abandons the critical points and proposes a moderately gradual model for the decrease of language acquiring efficiency when the optimal range of ages is missed. Therefore, in accordance with MSPH, it should be a linear relationship throughout between people's age and their learning speed or attainment of a language.

To some extent, the study of Flege (1999) contributed to justifying MSPH from the perspective of phonetic learning. Flege (1999), for the first time, summarized and concluded the linear relation between learners' L2 pronunciation and L2 AoA according to a series of research reports. The larger the L2 AoA, the stronger the foreign accents. Not as what the Critical Period Hypothesis had suggested, the abrupt turning point in the linear relation indicating the acute decrease of learning ability as well as the existence of a critical period did not emerge. Therefore, Flege proposed his "Speech Learning Model", arguing that people's L1 phonetic system was developing with the increase of the age, and when they were perceiving the L2 speech, people would connect the L1 and L2 phonetic systems, causing them to lose the L2 phonetic accuracy.

Birdsong and Molis (2001) replicated Johnson and Newport's (1989) study with the Spanish native speakers learning English as participants. It was testified possible that even though beyond the critical period, the ultimate attainment of L2 was still negatively related to the AoA of L2 and that the similarity degree between the mother language and the second language played crucial role in determining the L2 acquisition level. Besides, they also proved that many bilingual participants whose began L2 learning after their puberty were still able to reach the L1 level in terms of syntax.

In addition, Chai's (2013) research was much more all-sided. He explored the correlation between acquisition age of L2 Chinese and the performance in Chinese phonetics, grammar, vocabulary and Chinese character writing in HSK of 209 learners with 16 distinctive languages as their L1. The results showed that the impact of the L2 AoA on the L2 acquisition presented a modular feature. That is to say, the L2 AoA influence on L2 acquisition tempo varied according to the language aspects. A monotone decreasing trend of Chinese phonetic acquisition tempo was observed as the starting age increased in a negative correlative linear manner, but a "W"-shaped curve trend was found in other three aspects. Thus, no salient critical period effect appeared in all aspects.

As for those pre-puberty beginners, the starting age more dominantly affected the Chinese vocabulary acquisition, while as for those post-puberty beginners, the younger the age at which they started L2 acquisition, the more evident their phonological learning advantages. Moreover, the L2 AoA did significantly affect the possibility to reach the Chinese native-like proficiency. Chai's empirical study thus lent strong support to the rationality of MSPH's views about the relationship between the L2 AoA and L2 language acquisition.

Flege's, Birdsong and Molis' and Chai's findings can also be properly explained within the currently increasingly popular theory called "Emergentist Theory", which was established by Elizabeth Bates, et al. in the 1980s (Guo and Chen, 2007). Emergentist Theory denies the precondition of LAD and asserts that acquisition of language rules is based on and emerges naturally in the a large amount of language input. Then, on account of the input from different languages, there are two sets of language rules functioning in a bilingual's language system. This theory tries to interpret the L2 AoA effect of the Critical Period Hypothesis through the interaction between L1 and L2, that is, "competition", "resonance", "parasitism" and "entrenchment", among which "competition" and "entrenchment" are most crucial. The reason why adults seem to have more difficulties to learn another language is that, in comparison with children, they have taken in so much L1 input that when learning L2, the power of L1 entrenchment is relatively stronger than the competitiveness of the L2. Therefore, owing to the constraints of L1, it is less easier than children for adults to learn a second language, instead of the fault of missing the so-called critical period. Besides, the similarity of grammatical structure, phonetic features and other language aspects between L1 and L2 will strengthen the competitiveness of L2, accelerating the L2 acquisition efficiency. It is a viewpoint similar to the transfer theory, which seems to be more persuasive than the Critical Period Hypothesis, and many empirical studies' results have supported the "Emergentist Theory" (Tan, et al., 2003; Pallier, et al., 2003; Balaguer, et al., 2005). For example, because Chinese and English relatively belong to different language phonological systems, namely with Chinese being logographic and English being alphabetic, when processing Chinese characters and English words, people activates different zones in brain. In Tan, et al.'s (2003) fMRI experiments on Chinese-English bilinguals, when participants processed their L2(English) words, the zones strongly activated were still those L1(Chinese) word processing ones. This provided a persuasive explanation why adult L1 speakers had much more difficulties than the younger ones to learn L2 and develop a native-like L2 reading skill since adults had such a mature brain mechanism accustomed to processing L1 and they automatically applied this mechanism to L2 acquisition.

There is another factor which has been proved as closely correlated with L2 acquisition but otherwise, against the critical period. With regard to the influence of the L2 proficiency degree on the bilingual processing, numerous investigations on the second language acquisition have offered potent neurolinguistic proofs. Many fMRI studies found the evidence that the L2 proficiency could influence the L2 acquisition in the aspects of L2 semantic or syntactic processing (Perani, et al., 1998; Chee, et al., 2003; Xue, 2004). In accordance with their research results, on the one hand, the later (after the puberty) but high-proficiency L2 learners showed almost no difference in the brain activation pattern (or just with different activation degree) with the earlier (before the puberty) learners when processing L2; on the other hand, the later but high-proficiency L2 learners activated the same cerebral zones in L1 and L2 processing. In addition, the ERP research field also discovered something similarly important. For example, with L2 semantic anomalies, L2 learners' ERP responses were analogous to those of L1 processing (Ojima et al., 2005; Isel, 2007), whereas this consistency of cerebral activation zones was not obtained or testified by other ERP results in regard to syntactic and lexical processing without semantic factors (Osterhout, et al., 2006). By this token, it was not the L2 AoA but the L2 proficiency level that impacted language processing and through enough practice and learning, managing to make their L2 ultimate attainment catch up with the L1 or native speakers' level was totally possible for L2 learners. These neurolinguistic empirical evidence seems to show their support to one of the second language acquisition and processing theories named "Convergence Hypothesis" (Green, 2005). This hypothesis holds the standpoint that the neural cognitive mechanism is dynamic and the biological maturational constraints is incapable of impeding L2 learners from using the brain mechanisms of processing L1. That is to say, with the increase of language practice and the enhancement of language proficiency, the neural cognitive mechanism tends to be able to manage L1 and L2 similarly or in other words, the L2 learner, even those late adult learners, are able to have their L2 ultimate attainment close to the L1 level in some or even all language aspects.

3. Conclusion

From the above review of the research to testify the validness of the Critical Period Hypothesis in terms of the second language acquisition, it can be seen that no consensus has been reached and the controversy on this issue will continue. It may mainly be the following several reasons that have generated this long-lasting dispute.

First of all, different researchers used different methods, materials and subjects to test the critical period of second language acquisition from different perspectives of the second language, resulting in incommensurability between the results. Secondly, many empirical researches only tested or observed the L2 AoA effect on the second language performance and proficiency without controlling the years spent to learn L2, the participants' self-assessment standard of their L1 and L2, the time for which they lived and got educated in the L2 country, the participants' motivation and attitude towards the L2 learning, every participant's cognitive development level and so forth, which are variables extremely likely or certain to influence the L2 acquisition. Moreover, the differences between learning another language as a second language (learning in the corresponding foreign country, namely the natural language acquisition environment) and as a foreign language (learning in the learner's native country) are also worth paying attention to. Last but not the least, some researchers often determined whether there existed a critical period in the second language acquisition by assessing the L2 learning speed of participants of different L2 AoAs, but it was a serious mistake. The Critical Period Hypothesis emphasized that the ultimate attainment of learners with a late L2 AoA (after the puberty) will not reach the level of their mother language, but many research designs have neglected this key point because their participants have only learned their L2 for several years and their research could only be taken as testing the learning speed rather than the ultimate attainment. Furthermore, with regard to the authentic mother language level or native-like level, there is still no uniform measuring standard, bringing about more barriers to find an agreement in this research issue. In virtue of these above-mentioned reasons and the fact that the viewpoint of the "Critical Period Hypothesis" is too absolute and radical about the maturational constrains, it is almost impossible to obtain a consensus on this issue. Therefore, many scholars have suggested that it should be more suitable to substitute "age effect" for the "critical period" to explore the relationship between age and language acquisition (DeKeyser, 2000; DeKeyser, et al., 2010; Ma, 2016). At the same time, Other increasing popularity theories and hypothesis such as the improved hypotheses MCPH and MSPH based on the original Critical Period Hypothesis, Speech Learning Model, Emergentist Theory, Convergence Hypothesis and so on seem to provide several more reasonable, comprehensive and scientific models to explain the correlation between age, L1 and L2 language acquisition in full aspects of languages, but more empirical evidences are still necessary to fortify the verification.

Despite of the lack of the agreement whether there is a critical period in second language acquisition, some meaningful pedagogical implications still deserve mentioning. For example, the starting age actually influences the L2 acquisition especially in phonetics. It is more helpful for L2 learners to develop a native-like or more standard accent if they start learning L2 much earlier. Besides, according to the results opposing the existence of the critical period, the years to learn L2, the L2 proficiency, the similarity degree between L1 and L2, the effects of the mother language can also function interactively to facilitate or hinder the second language acquisition. These findings can provide useful implications for second language teaching methods and the establishment of policies related to L2 curriculum setting in school. First of all, it is deniable that L2 acquisition age is one of the crucial factors in L2 acquisition, but this relationship should be just regarded as a correlation instead of an absolute causality or age-determinism. Since it is in fact far from possible to find a so-called "Optimal Age" to learn a second language, factors like an individual learner's intellectual, emotional, cognitive and physiological development, social environment and so on should be all taken into consideration in language teaching. Besides, as for the opinions like "the earlier the children start to learn a foreign language, the better their achievement they will get", no enough scientific evidence has been found to support it. Along with the above findings against the critical period for language acquisition, Piaget's division of children's cognitive ability development stages seems to violate this opinion and worthwhile for reference. Eventually, in recent decades, the exploration of age effect has been fruitful in foreign countries. In contrast, there are relatively fewer domestic studies in China, many of which are macroscopical discussions and research review of studies abroad on the critical period of second language acquisition (Liu, 2003; Guo and Chen, 2007; Cui, 2013; Ma, 2013, 2016;), except a small number of empirical studies (Xue, et al., 2004; Xin and Zhou, 2006; Ma, 2012; Chai, 2013). The research methods of a majority of Chinese studies are also lacking in persuasion, so more scientific and cognition-related methods like ERP, eye-tracking and fMRI are recommended in future studies in China. All in all, There is still a long way to go to conduct the sufficient and scientifically reasonable theoretical analysis and empirical research on the laws and patterns of people's second language acquisition, especially in exploring the age effect on it.

References

- Abrahamsson, N., & K. Hyltenstam. (2009). Age of onset and nativelikeness in a second language: Listener perception versus linguistic scrutiny. *Language Learning*, 59(2), 249-306.
- Balaguer, R.D., Sebastian-Galles, N., Diaz, B., & Rodriguez-Fornells, A. (2005). Morphological processing in early bilinguals: An ERP study of regular and irregular verb processing. *Cognitive Brain Research*, 25(1), 312-327.

- Bates, E. (1984). Bioprograms and the innateness hypothesis. *Behavioral and Brain Sciences*, 7, 188 -190.
- Birdsong D. (1999). *Second Language Acquisition and the Critical Period Hypothesis*. Mahwah, NJ: Lawrence Erlbaum Associates.
- Birdsong, D., & Molis, M. (2001). On the Evidence for Maturation Constraints in Second-Language Acquisition. *Journal of Memory and Language*, 44(2), 235-249.
- Chee, M. W., Soon, C. S., & Lee, H. L. (2003). Common and Segregated Neuronal Networks for Different Languages Revealed Using Functional Magnetic Resonance Adaptation. *Journal of Cognitive Neuroscience*, 15(1), 85-97.
- Chomsky, N. (1965). *Aspects of the Theory of Syntax*. Cambridge: The MIT Press.
- Chomsky, N. (1980). On Cognitive Structures and their Development: A reply to Piaget. In M. Piattelli-Palmarini (ed.), *Language and Learning: The debate between Jean Piaget and Noam Chomsky*. Harvard University Press.
- Curtiss, S. (1977). *Genie: A psycholinguistic study of a modern-day "wild child"*. New York: Academic Press.
- DeKeyser, R. M. (2000). The robustness of critical period effects in second language acquisition. *Studies in Second Language Acquisition*, 22(4), 499-533.
- DeKeyser, R., Alfshabtay, I., & Ravid, D. (2010). Cross-Linguistic Evidence for the Nature of Age Effects in Second Language Acquisition. *Applied Psycholinguistics*, 31(3), 413-438.
- Dirix, N., & Duyck, W. (2017). An eye movement corpus study of the age-of-acquisition effect. *Psychonomic Bulletin & Review*, 1-7.
- Flege, J. E., Yenikomshian, G. H., & Liu, S. (1999). Age constraints on second-language acquisition. *Journal of Memory and Language*, 41(1), 78-104.
- Friedmann, N., & Rusou, D. (2015). Critical period for first language: the crucial role of language input during the first year of life. *Current Opinion in Neurobiology*, 35, 27-34.
- Green, D. W. (2005). The neurocognition of recovery patterns in bilingual aphasics. In J. F. Kroll & A. M. B. de Groot (Eds), *Handbook of bilingualism: Psycholinguistic approaches* (pp.516 -530). New York: Oxford University Press.
- Isel, F. (2007). Syntactic and referential processes in second-language learners: event-related brain potential evidence. *Neuroreport*, 18(18), 1885-1889.
- Johnson, J. S. (1992). Critical period effects in second language acquisition: The effect of written versus auditory materials on the assessment of grammatical competence. *Language Learning*, 42(2), 217-248.
- Johnson, J. S., & Newport, E. L. (1989). Critical period effects in second language learning: The influence of maturational state on the acquisition of English as a second language. *Cognitive Psychology*, 21(1), 60-99.
- Kim, K. H., Relkin, N., Lee, K. M., & Hirsch, J. (1997). Distinct cortical areas associated with native and second languages. *Nature*, 388(6638), 171-174.
- Lane, H. (1976). *The wild boy of Aveyron*. Cambridge, MA: Harvard University Press.
- Lenneberg, E. H. (1967). *Biological Foundations of Language*. New York: Wiley.
- Long, M. H. (1990). Maturation constraints on language development. *Studies in Second Language Acquisition*, 12(3), 251-285.
- Long, M. (2005). Problems with supposed counter-evidence to the critical period hypothesis. *International Review of Applied Linguistics in Language Teaching*, 43(4), 287-317.
- Ojima, S., Nakata, H., & Kakigi, R. (2005). An ERP Study of Second Language Learning after Childhood: Effects of Proficiency. *Journal of Cognitive Neuroscience*, 17(8), 1212-1228.
- Osterhout, L., Mclaughlin, J., Pitkanen, I., Frenckmestre, C., & Molinaro, N. (2006). Novice Learners, Longitudinal Designs, and Event-Related Potentials: A Means for Exploring the Neurocognition of Second Language Processing. *Language Learning*, 199-230.
- Oyama, S. (1976). A sensitive period for the acquisition of a nonnative phonological system. *Journal of Psycholinguistic Research*, 5(3), 261-283.
- Pallier, C., Dehaene, S., Poline, J., Lebihan, D., Argenti, A. M., Dupoux, E., & Mehler, J. (2003). Brain Imaging of Language Plasticity in Adopted Adults: Can a Second Language Replace the First?. *Cerebral Cortex*, 13(2), 155-161.
- Perani, D., Paulesu, E., Galles, N. S., Dupoux, E., Dehaene, S., Bettinardi, V., ... & Mehler, J. (1998). The bilingual brain. Proficiency and age of acquisition of the second language. *Brain*, 121(10), 1841-1852.
- Penfield, W. & Roberts, et al. (1959). *Speech and Brain Mechanisms*. New York: Atheneum.
- Snow, C., & Hoefnagel - Hohle, M. (1982). Age differences in the pronunciation of foreign sounds. In S. Krashen, R. Scarcella & M. Long (Eds.), *Child - adult differences in second languages acquisition*. Rowley, MA: Newbury House, 84-92.

- Tan, L. H., Spinks, J. A., Feng, C. M., Siok, W. T., Perfetti, C. A., Xiong, J., ... & Gao, J. H. (2003). Neural Systems of Second Language Reading Are Shaped by Native Language. *Human Brain Mapping*, 18(3), 158-166.
- Wartenburger, I., Heekeren, H. R., Abutalebi, J., Cappa, S. F., Villringer, A., & Perani, D. (2003). Early Setting of Grammatical Processing in the Bilingual Brain. *Neuron*, 37(1), 159-170.
- Weberfox, C. M., & Neville, H. J. (1996). Maturation constraints on functional specializations for language processing: Erp and behavioral evidence in bilingual speakers. *Journal of Cognitive Neuroscience*, 8(3), 231-256.
- Xue, G., Dong, Q., Jin, Z., Zhang, L., & Wang, Y. (2004). An fMRI study with semantic access in low proficiency second language learners. *Neuroreport*, 15(5), 791-796.
- Chai, X. S. (2013). An empirical study of the Critical Period Hypothesis in the acquisition of Chinese as a second language. *Foreign Language Teaching and Research*, 9, 692-706.
- Cui, G. (2011). On Research of the Critical Period Hypothesis of Language Acquisition. *Foreign Language Education*, 3, 48-51.
- Guo, J. J., & Chen, B. G. (2007). The Emergentist Theory and Its New Explanation for the Age Effect of Second Language Acquisition. *Journal of Psychological Science*, 2, 500-503.
- Liu, Z. Q. (2003). A Critique of the Critical Period Hypothesis in L2 Acquisition. *Contemporary Linguistics*, 3, 158-172.
- Ma, C. L. (2012). Age-related Factors in Second Language Acquisition— An Investigation of the Influence of Starting Age of English Learning of Ethnic Minority University Students on Their Academic Achievements. *Journal of Research on Education for Ethic Minorities*, 23(109), 106-108.
- Ma, Z. (2013). Age Effect and skill Acquisition Theory in Second Language Acquisition. *Contemporary Foreign Languages Studies*, 9, 1-9.
- Ma, Z. (2016). A Synthetic Review of Research on Age Effects in SLA: What, How and Why. *Foreign Languages Research*, 5, 52-57.
- Xin, K. & Zhou, S. L. (2006). The Influence of Age on Second Language Acquisition: An Empirical Study on the Critical Period Hypothesis. *Foreign Language Education*, 27(4), 80-82.