

Mechanism of Inner Speech in Silent Reading Activity

Neurolinguistic Studies

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ABSTRACT

This research is motivated by the existence of the inner speech phenomenon that occurs when someone reads silently. This phenomenon is allegedly related to gathering and processing information when the reading process is carried out. This study investigates the mechanism and determines the optimal conditions in the inner speech mechanism. This study aims to compare the inner speech mechanism in reading scientific articles in Indonesian and English. The method used in this study is a multiple qualitative case study. Qualitative data were used to describe the comparison of inner speech in reading scientific articles in Indonesian and English. Data processing produces three levels of categories which are divided into: (1) high reading score; (2) average reading score and; (3) low reading score. These data are correlated to produce an optimal inner speech area in the process of silent reading. This study concludes that (1) the optimal inner speech mechanism used in silent reading of Indonesian articles is BA-18, while in English, it is BA-10 and BA-11; (2) the difference in Brodmann Area localization in silent reading activity is influenced by cognition and the language used by the respondents.

Keywords: Brodmann area, inner speech, silent reading, sLORETA.

1. INTRODUCTION

Unconsciously, humans carry out inner speech activities or inner voices. Inner talk is defined by Guerrero (in Morin, Uttl, & Hamper, 2011) as internal talking to oneself without a voice. This inner speech activity is considered essential in the scope of psychology because this activity can affect positive emotions, cognitive, and human consequences in behavior (Alderson-Day & Fernyhough, 2015), for example, in making decisions solving problems, and setting goals. In the activity of inner speech, language is produced in a person's mind, meaning that everyone experiences subjective experiences without any audible articulation.

Heavey and Hurlburt (in Vicente & Martinez Manrique, 2011) revealed that humans do the inner speech in their subconscious and take 26% every day. This statement shows that inner speech has control in evaluating situations experienced by oneself and others. Morin et al. (2011) stated that an evaluation process is a form of mediation of the role of inner speech that controls individual awareness. Thus, inner speech is considered essential as a mediator between verbal cognition and

human behavior related to working memory. Thus, inner speech is often used in activities carried out by humans without realizing it. One of the activities involving inner speech is silent reading. Silent reading is a reading activity, usually done by students because students must read many scientific articles in various languages for academic purposes.

When reading silently, the pattern of the inner speech mechanism that occurs in each person will be different. According to Samuels, Hiebert, and Rasinski (2010), this difference is influenced by three things, namely language patterns, intonation patterns, and other language elements. Therefore, in a bilingual society, the first language often affects the second language learning process. This language learning process causes the pattern of inner speech that occurs in the human brain to be involved. These differences in patterns can be identified through neural correlations in the human brain.

In a series of reading activities, neural correlations are involved in processing various information in the brain. These neural correlations are related to eye movement, working memory activity, the brain that regulates

language, and various other activities. In silent reading activities, the speed of processing different information is limited by the capacity of eye movements, while during oral reading, the process is determined by word production (Samuels et al., 2010).

Neural correlation is a neural process directly related to specific conscious experiences when stimulated and aroused nerves (Aru, Bachmann, Singer, & Melloni, 2012). We used electroencephalography to find out the neural correlation that occurs in the silent reading activity. Electroencephalography or EEG is an electrophysiological monitoring method that occurs in the brain. It aims to record the brain's electrical activity. EEG measurements help investigate phenomena in the human brain, a subjective phenomenon that occurs when reading silently, such as inner speech (Nurhadi, Rahma, & Dewi, 2021).

Inner speech on silent reading activities has been much researched, some of which include: What is that little voice in my head? Inner speech phenomenology, its role in cognitive performance, and its relation to self-monitoring (Bertolotti et al., 2014); Inner speech during Silent Reading Reflects the Reader's Regional Accent (Filik & Barber, 2011); Silent Reading of Direct versus Indirect Speech Activates Voice-selective Areas in the Auditory Cortex (Yao, Belin, & Scheepers, 2011); Self-reported Inner speech Use in University Students (Morin, Duhnych, & Racy, 2018); How Silent Is Silent Reading? Intracerebral Evidence for Top-Down Activation of Temporal Voice Areas during Reading (Bertolotti, 2012). Research on inner speech in silent reading that focuses on reading scientific articles in two different languages with EEG recording and measurement has never been done. Whereas inner speech currently has an essential role in metacognition, awareness, and self-understanding (Morin, 2005). Therefore, researchers are interested in investigating the mechanism of inner speech in the silent reading of scientific articles in different languages, Indonesian and English. This study investigates the interrelationships of the part of the brain involved when inner speech activity occurs. After that, the optimal inner speech mechanism was also be tested in the silent reading process.

2. THEORETICAL FRAMEWORK

2.1. Inner speech

Inner speech can be interpreted as a subjective experience of language without audible articulation. Inner speech produces a language in a person's mind or mind. Guerrero (in Morin et al., 2011) defines inner speech as internal speech to oneself without sound.

In another theory, Jones and Fernyhough (2007) assume that inner speech has several different properties from external utterances. First, inner speech has its

dialogue quality. Dialogue is fundamental because it is formed when external dialogue gradually develops into internal dialogue—for example, a conversation between a child and his caregiver. The gradual internalization of this development ensures that inner speech has an inherently dialogical nature (Fernyhough, 1996; Fernyhough, 2009). Second, inner speech is thick. It has been composed of syntactic processes and semantic abbreviations (Vygotsky, 1987). Third, namely, the extent to which inner speech can involve the presence of other people. Lastly and most importantly, inner speech serves to evaluate oneself, others, and specific situations. The evaluation is a mediating form of inner speech that plays a control in an individual's self-awareness (Morin et al., 2011).

There are various theoretical perspectives on inner speech. There are two that have been shown to affect cognitive function (Larrain & Haye, 2012; Morin, 2005; Oppenheim & Dell, 2010). One is concerned with mediating verbal cognition and behavior, and the other is concerned with working memory. For example, in child-caregiver relationships, the development of verbal mediation is described as how children become able to use language and other sign systems to regulate their behavior. With inner speech, a child will gradually take on greater strategic responsibility for activities that previously required input from other experts, such as caregivers (Alderson-Day & Fernyhough, 2015). In other words, inner speech results from a developmental process in which linguistic interactions, such as between caregiver and child, are internalized. Linguistically mediated explanations to complete a task become an internalized conversation with oneself (Chella, Pipitone, Morin, & Racy, 2020).

2.2. Silent Reading Activity

The process of silent reading is better known as "reading silently" by ordinary people. Silent reading is considered more effective in obtaining information because silent reading requires high concentration. Therefore, teachers often apply this silent reading technique to make students more skilled in reading fluently. Even Gardiner (as cited in Siah & Kwok, 2010) states that silent reading relates to increasing vocabulary acquired by students. Silent reading can also increase students' self-confidence, motivation, and reading skills.

Although silent reading is considered producing more words than spoken reading, making words become more stable when entering the adolescent phase. This reason is what causes the production of words when reading silently more than when reading orally. But even so, there is no guarantee that silent reading technique has the time effectiveness of everyone's word production (Alderson-Day & Fernyhough, 2015).

2.3. Electroencelelography

Electroencelelography, better known as EEG, is a method of recording electrical activity in the brain by placing a device along the scalp. The EEG device can measure voltage fluctuations generated by ion currents in brain neurons (Tatum, Husain, Benbadis, & Kaplan, 2008). The results of the EEG image show recorded electrical activities from two locations of documented brain functions (Tatum et al., 2008). The bias of this EEG method is used to determine disorders that occur among people with epilepsy or Alzheimer's. The EEG only shows the part of the brain that is stimulated and does not show what produces it.

The results of the EEG recording can be determined based on four things, namely, 1) the rhythmic pattern of oscillations and voltage waves in the same area in both hemispheres of the brain; 2) waveform, for example, sharp waves, spikes, compound spikes, and slow or fast waves, etc.; 3) the type of frequency, such as: gamma, beta, alpha, theta, and delta, and 4) visualization of brain mapping (brain mapping).

EEG produces a picture of electrical activity in the brain, which is represented as waves with varying frequency, amplitude, and shape based on parameters including place, voltage (amplitude), shape (morphology), frequency, rhythm, continuity, number of visible waves and where certain clinical events occur (wake up or fall asleep). Although EEG has several advantages, such as having the ability to measure brain activity quickly, this method also has limitations. EEG has a low signal-to-noise ratio (SNR). The measured brain activity is often interleaved with environmental, physiological, and other specific actions with the same or greater amplitude.

2.4. Brodmann Area

The Broadman area is functional in the cerebrum or cerebrum, divided into four major parts: the occipital lobe, frontal lobe, parietal lobe, and temporal lobe. Broadman divides these functional areas into 43 sections which are described as follows.

- 1) Frontal Eye Field, namely Broadman Areas 4 and 6. This section has a function that regulates movement and behavior in humans, for example, BA-4, which functions to plan and carry out activities in muscles to contract, such as winking, hand movements, and muscle arrangement. Meanwhile, BA-6 functions to plan and carry out human behavior, for example, planning, reading lips, understanding speech, interpreting language, self-reflection, smiling, and laughing.
- 2) The motor language area (Broca) is BA-44 and BA-45. This area has a function to process speech production, such as language comprehension (written and spoken), intonation, hand movements, and others. The inferior Broca's area is used to understand semantic processes (meaning words), and the posterior area is used to realize phonology (sounds of words).
- 3) Audition, namely BA-9, BA-10, BA-11, BA-46, and BA-47. In general, this section deals with the regulation of memory and cognition functions.
- 4) Wernicke; BA-22, namely the sensory language area.
- 5) Cognition; BA-26, BA-27, BA-29, BA-33, and BA-35
- 6) Emotions; BA-38
- 7) Somatosensory: BA-1, BA-2, BA-3, BA-5, and BA-40, namely primary sensory areas
- 8) Motors; BA-4, BA-6, and BA-32
- 9) Taste Perception; BA-43
- 10) Visions; BA-17, BA-18, and BA-19
- 11) Visual-Parietal; BA-7 and BA-39
- 12) Visual-Temporal; BA-20, BA-21, and BA-37
- 13) Olfaction; BA-34

3. METHOD

This study used a qualitative method. We used the same methods and techniques as in the previous research by Nurhadi et al. (2021). The primary data sources of this study were 20 respondents who were native Indonesian speakers, consisting of 5 male respondents and 15 female respondents from Bandung.

After the respondents fills out the consent form, the respondent will be given two stimuli, namely, 1) Reading scientific articles in Indonesian and 2) Reading scientific articles in English.

The data will then be retrieved by observing, recording, and measuring EEG through the Open Brain-Computer Interface (OpenBCI) hardware and software. The hardware is a Cyton+Daisy 32bit Board with 16 channels and 125Hz recording samples and is connected via the OpenBCI Dongle to the ASUS A442UQ laptop, while the software uses a standalone application from OpenBCI. From these devices, electrical signals will be recorded in the brain through electrodes that are installed based on the International System 10-20 points, namely: Fp1 (Frontal Polar 1), Fp2, F3 (Frontal 3), F4, F7, F8, C3 (Frontal 3). Central 3), C4, T3 (Temporal 3), T4, T5, T6, P3 (Parietal 3), P4, O1 (Occipital 1), O2, and reference points A1 (Earlobe 1), and A2. (Electrode installation point based on complete MNI coordinates in appendix 3.2)

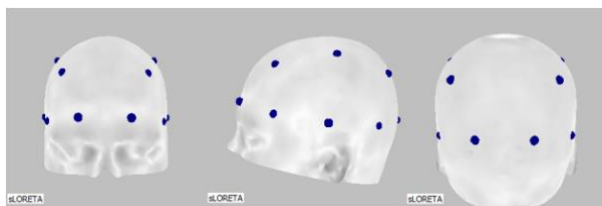


Figure 1 Electrode mounting points with MNI coordinates for tomographic map analysis using sLORETA.

Table 1. Recapitulation of the Brodmann area localization position in inner speech in reading scientific articles in Indonesian and English

AREA BRODMAN	INDONESIA	ENGLISH
BA-2	2	0
BA- 6	0	3
BA-7	0	1
BA-10	0	5
BA-11	0	5
BA-18	10	4
BA-19	5	1
BA-20	1	0
BA-21	1	0
BA-37	1	0
BA-47	0	1
TOTAL	20	20

The procedure for collecting EEG data to describe the mechanism of inner speech in silent reading of scientific articles is carried out through the following steps.

- 1) Recording of EEG data when reading scientific articles is carried out;
- 2) Numbering on the respondent's EEG recording file based on gender, order of data collection, respondent code number, article language and
- 3) Recheck the results of the raw data EEG recording.

After the EEG data is collected, the data will be processed using the sLORETA Key v20200709 software. Before the EEG data is imported, the electrode placement is registered to MNI (Montreal Neurological Institute) coordinates. Then the electrodes were transformed into a matrix (.sxyz) for sLORETA analysis. The pre-prepared EEG data is computed in the form of sLORETA (.slor). Then the computational results are opened in the LORETA Key Viewer. The peak of the EEG .slor data (maximum value) at each frequency was used as the observation point. The position of Brodmann's area and the position of brain localization were analyzed from these observation points. This sLORETA analysis obtained a topographic map showing the dominant locations used in reading Indonesian and English

scientific articles. The predominant Brodmann Area localization is then interpreted based on the Brodmann Area function theories.

Qualitative data describes the mechanism of inner speech based on topographic maps and neural correlations based on electric current patterns. Meanwhile, quantitative data were used together with the results of the respondents' reading tests. The respondent's reading test results will then be correlated to see the most optimal inner speech area in the process of silently reading Indonesian scientific articles and English scientific articles.

4. RESULTS AND DISCUSSION

4.1. Inner speech on Reading Indonesian and Indonesian Scientific Articles

The description of the condition of inner speech in this study was carried out through tomographic analysis based on sLORETA. The results of the sLORETA analysis are described as follows.

The data that has been collected is then processed using sLORETA (Standardized Low-Resolution Brain Electromagnetic Tomography) software to detect inner speech in the Brodmann area when reading Indonesian scientific articles. The results of the data processing show that there are three level categories which are divided into: 1) high reading score category; 2) category of the average reading score and; 3) low reading score category. The localization area is shown in table 1 below. Figures and tables should be placed either at the top or bottom of the page and close to the text referring to them if possible.

Based on the data obtained from observations, it can be seen that in the inner speech of silently reading scientific articles in Indonesian, the dominant part of the area is BA-18, i.e. as many as ten respondents use the BA-18 section or as much as 50%. But even so, some use the BA-19 section as many as five respondents or 25% of the total respondents. Meanwhile, in the inner speech of silently reading scientific articles in English, four sections of the Broadmann Area dominate, namely BA-10 with five respondents (25%), BA-19 with five respondents (25%), BA-18 with four respondents (20 %), and BA-6 as many as three respondents (15%).

From these two kinds of data, it can be seen that two Broadmann Areas dominate the localization of reading inner speech, both reading scientific articles in Indonesian and in English, namely BA-18 and BA-19. The localization of BA-18 and BA-19 is in the Occipital Lobe, which is an area that has a function as the center of vision. In this case, BA-18, part of the Occipital Lobe Cortex and known as V2, functions to detect light and three-dimensional images. Research shows that the BA-18 region has a central role in memory storage, converting short-term to long-term memory, and object

identification. BA-19, located in the same cortex, namely the Occipital Lobe, also has a similar role, namely being a point of differentiation between the two visual streams. The dorsal region contains neurons that are sensitive to movement, and the abdomen region can recognize objects (Lopez-Aranda, 2009).

4.2. Localization of Inner Speech Reading Scientific Articles in Indonesian and English

Based on the localization of Brodmann's area through the sLORETA analysis in the previous subsection, the localization of inner speech from the anterior (front) to the posterior (back) can be shown in Table 2.

Table 2 indicates that in inner speech, the dominant part of the reading activity is the occipital lobe area in reading Indonesian articles and the frontal lobe in reading English articles. In the Indonesian reading inner speech, 14 respondents (70%) used the Occipital Lobe area dominantly. However, there are four respondents (20%) who actively use the Frontal Lobe. Meanwhile, 14 respondents (70%) used the frontal lobe in the inner speech reading English. However, as many as five respondents (25%) used the occipital lobe.

Inner speech reading in Indonesian and localized English in the frontal lobe is spread out in Table 3. In the condition of inner speech, the activity of reading scientific articles in the Indonesian language does not find the use of the frontal area; this is different from the inner speech of reading scientific papers in English, which predominantly uses the frontal region. Based on the table above, it can be seen that the most dominant area is the Superior Frontal Gyrus area. Boisgueheneuc et al. (2006) said that this area is an area that has a high cognitive contribution, especially working memory. In

Table 2. Localization of Inner Speech Reading Scientific Articles in Indonesian and English

Localization of Inner Speech	Indonesia	English
Frontal	-	14
Temporal	4	-
Parietal	2	1
Occipital	14	5
TOTAL	20	20

Table 3. Localization of Inner Speech in the Frontal Lobe

Frontal Lobe Area	Indonesia	English
Superior Frontal Gyrus	-	9
Middle Frontal Gyrus	-	2
Precentral Gyrus	-	2
Rectal Gyrus	-	1
TOTAL	0	14

reading scientific articles, cognitive function will be activated when the reading comprehension process takes place. Inner speech reading in Indonesian and localized English in the Temporal Lobe is spread out as shown in table 4.

Meanwhile, in the Temporal Lobe, the Fusiform Gyrus is the dominant area in reading scientific articles in Indonesian. The Fusiform Gyrus is also known as the Lateral Occipitotemporal Gyrus because it is located between two lobes, namely the Temporal Lobe and the Occipital Lobe. This area is concerned with higher-order visual recognition, including word recognition (Grill-Spector & Weiner, 2014).

Inner speech reading in Indonesian and localized English in the Parietal Lobe is spread out as shown in table 5. Table 5 shows that the Parietal Lobe is not too dominant in the condition of inner speech reading scientific articles. However, there are two points: Superior Parietal Lobule in inner speech reading scientific papers in English and Postcentral Gyrus in inner speech reading articles in Indonesian as many as two respondents (10%). The Superior Parietal Lobule plays a role in processing spatial orientation. At the same time, the Postcentral Gyrus is the location of the primary somatosensory cortex, namely the sensory receptive area, especially the sense of touch.

Inner speech reading in Indonesian and localized English in the Occipital Lobe is spread out in Table 6.

Table 4. Localization of Inner Speech in the Temporal Lobe

Temporal Lobe Area	Indonesia	English
Fusiform Gyrus	2	-
Inferior Temporal Gyrus	1	-
Middle Temporal Gyrus	1	-
TOTAL	4	0

Table 5. Localization of Inner Speech in the Parietal Lobe

Parietal Lobe Area	Indonesia	English
Superior Parietal Lobule	-	1
Postcentral Gyrus	2	-
TOTAL	2	1

Table 6. Localization of Inner Speech in the Occipital Lobe

Occipital Lobe Area	Indonesia	English
Fusiform Gyrus	2	-
Superior Occipital Gyrus	-	-
Middle Occipital Gyrus	6	2
Inferior Occipital Gyrus	5	-
Lingual Gyrus	-	3
Cuneus	1	-
TOTAL	14	5

Based on table 6, the Lingual Gyrus, Middle Occipital Gyrus, and Inferior Occipital Gyrus are dominant in the Occipital Lobe area. Middle Occipital Gyrus and Inferior Gyrus in reading scientific articles in Indonesian and Lingual Gyrus in reading scientific papers in English.

Standring (2016) reveals that the Lingual Gyrus, also known as the Medial Occipitotemporal Gyrus, is a brain structure related to vision. This section functions to identify letters and recognize words. It also plays a role in encoding visual memory and logical sequences of events. In reading activities, the process of encoding letters is believed to be the dominant activity. This section plays an active role when given the condition of inner speech; this condition is also called selective visual attention.

Middle Occipital Gyrus and Inferior Occipital Gyrus are involved in visual processing. The Middle Occipital Gyrus has more of a role in visual-spatial information, while the Inferior Occipital Gyrus has more role in visual-facial communication (facial recognition). In reading activities, usually, both work in tandem with the Amygdala when accessing memory (Amunts et al., 2005).

5. CONCLUSION

Based on the results of the research, it can be concluded that (1) the optimal inner speech mechanism used in silent reading of Indonesian articles is BA-18, while in English, it is BA-10 and BA-11, (2) the difference in Brodmann Area localization in silent reading activity is influenced by cognition and the language used by the respondents.

The implications of the findings in this research can be applied in language education, especially in the teaching of reading skills. By knowing the most optimal localization of the area in silent reading activity, it can be used as reference material in determining learning strategies to improve reading comprehension. Research on inner speech in silent reading activity in the field of neurolinguistic is still rarely performed. This research is expected to add resources to develop further research.

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