Electrophysiological Indices of Sentence Processing in Spanish-English Bilingual Teenagers

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Abstract

Bilingual speakers show remarkable flexibility in their ability to control their language output. They can restrict their speech to one language only but also intentionally switch between languages in bilingual settings; language selection refers to the cognitive mechanism that allows bilinguals to communicate in both languages and to switch between languages depending on the listener.

The aim of this research was to determine if bilingual and monolingual teenagers process sentence meaning similarly by monitoring their brain patterns using an EEG. An electroencephalogram (EEG) is a test used to detect abnormalities related to electrical activity of the brain. Six participants (5 female, 1 male and mean age- 17) were recruited from Briarcliff High School, three were bilingual (Spanish/ English) and three were monolingual (English).

Results showed that monolingual and bilingual high school teenagers process coherent sentences in a story similarly. All of the subjects used the same parts of the brain to understand the story. However, monolingual teenagers processed the incoherent sentences in a story differently. It took the bilingual teenager more time to understand the story as a whole. Bilingual teenagers also took a longer time to understand what incoherent sentences mean in a story. Both bilingual and monolingual teenagers understand the meaning of sentences; however they differed in understanding the sentences order in a coherent or incoherent story.

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Introduction

1.1*Languages and Different forms of Bilingualism*

There is no evidence of any human group who does not speak at least one language. At present, more than 6,000 spoken languages are used in the world. Moreover, mankind has a unique ability to learn more than one language. This is thought to be mediated by functional changes in the brain (Ulrike Halsband, 2006).

Language use consists of socially and cognitively determined selection of behaviors according to the goals of the speaker and the context of the situation. Since it exists in the form of several different languages, it is not surprising that some nations are officially bi- or multilingual. Obviously, closely related languages (e.g. Spanish and Italian) share much semantic overlap; in contrast, unrelated languages (e.g. Finnish and English) do not have much in common. There are different forms of bilingualism. “Simultaneous” bilingualism refers to the learning of two languages as “first language”. Infants who are exposed to two languages from birth will become simultaneous bilinguals. In other words, a person who is a simultaneous bilingual advances from speaking no languages at all to speaking two languages at once. In contrast, “consecutive” or “successive bilingualism” refers to the learning of one language after already knowing another. This is the situation for all those who become bilingual as adults, as well as for many who became bilingual earlier in life (Ulrike, 2006).

Bilinguals may switch from language to language, alternating their verbal expression between the two languages. Other bilinguals may mix linguistic elements from various languages within a single sentence. Switching and mixing are frequent in normal bilingual speakers, but they reflect a pathological behavior when produced during conversation (Franco Frabbo, 2001). Bilinguals switch and mix languages, while monolinguals switch and mix registers; bilinguals translate from one language into another, while monolinguals may paraphrase from one register to another (i.e. they can express the same concept addressing their own little child or an audience of experts) (Paradis, 1993, 1998).

1.2 *Language Acquisition*

Language acquisition is the process by which the language capability develops. Language acquisition concerns the development of language in children, while second language acquisition focuses on language development in adults.

1.3 *Storing and Communicating Information*

Language, like other functions, requires the information to be learned and stored in memory. Brian activated in learning a specific stimulus or tasks are also activated in memory for the stimulus or task. Memory, is seen as synchronousing electrical activity across neurons in a neural circuit responding to some stimulus attribute or task. The basis for storing and communicating information in the brain signals are passed between neurons (cell bodies) with a long process called an axon. A chemical message (neurotransmitter) is released at a terminal (synapse) at the end of an axon and received on another neuron, often at a dendrite (extension of the neuron). The chemical message leads to changes in the electrical potential of receiving neurons (Zigmond, Fundamental Neuroscience).

1.4 *Principles of Neuroscience*

Neural mechanisms of cognitive control enable us to initiate, coordinate and update behavior. Central to successful cognitive control is the ability to suppress actions that are no longer relevant or required. Intelligent behavior in a rapidly changing environment requires continual monitoring and updating of actions. A key determinant of successful cognitive and motor control is response inhibition: the ability to suppress behaviors that are inappropriate, unsafe, or no longer required.

1.5 *Bilingual Language Production*

Behavioral techniques have yielded considerable progress but current data leave a number of questions unresolved and do not reveal the full scope of the control process involved. Compared to monolingual people, bilingual are slower to name the picture but do not differ in the time required to access their meaning in order (Gollan, Montoya, Fennema- Notestline & Morris, 2005). Bilinguals have conceptual representation consisting of two different lexical representations that are used by different grammatical systems (De Groot, 1993; Francis, 1999; Krool & Stewart, 1994). The lexical-semantic system in a proficient bilingual consists in the man of distinct lexically and syntactically specified concepts and their associated word forms.

1.6 *Neurocognition*

A relative delay in naming reflects the fact that bilinguals are in fact less practiced in naming words in either of their languages. The bilingual speaker should not simply be considered the sum of two monolingual speakers, so monolingual language production models generally fail to explain the practically of bilingual production. Bilinguals have conceptual representation linked of two different lexical representations that are used by different grammatical systems (De Groot, 1993; Francis, 1999; Kroll & Stewart, 1994). The lexical-semantic system in a proficient bilingual consists in distinct lexical and symantic specified concepts and are associated words and forms.

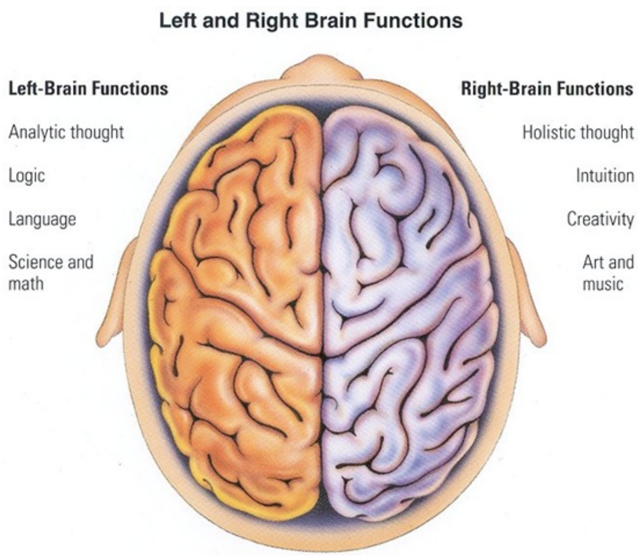
1.7 *Brain imaging of bilingual processing using functional brain imagining and neurophysiological techniques*.

Recent studies have shown variation in the cerebral activation in the context of processing native and foreign languages (Dehaene et al., 1997; Kim et al,. 1997; Klien et al.,; 1994; Peranie et al.,; 1996, 1998). It has been suggested that there are differences in the cerebral organization of language depending on the age of acquisition and learning strategies (Neville et al., 1992, 1997; Weber fox and Neville, 1996). However it is still unknown how multilingual processing takes place in the brain.

Using functional magnetic resonance imaging (fMRI), which is a type of MRI scan, Kim et al, (1997) reported that the mother tongue in localized in Broca's area and each newly acquired language in anterior portions of Broca's area. The second language tended to have a more diffuse representation in the left hemisphere than did the mother tongue (Dehaene et al., 1997). Furthermore it has been proposed that the left supramarginal gyrus in the partial lobe controls switching form one language to another (Prie et al., 1999).

1.8 *Brain Anatomy*

The central nervous system consists of spinal cord and brain. The brain is then further divided into the forebrain, midbrain, and hindbrain. The cerebrum is divided into two hemispheres, the left and the right, separated by the longitudinal fissure. Anatomically these are identical in form, each being split into four lobes: the frontal lobe, the partial lobe on the top the temporal lobe on the side, and the occipital lobe at the back. The specific regions that is responsible for speech, which is located in the left hemisphere of most people. It is known that the dominant left hemisphere of the human brain is critical for producing and comprehending spoken language (U. Halsband/ Journal of Physiology, Paris (2006)).



https://blogs.wharton.upenn.edu/staff/remurphy/WindowsLiveWriter/OnLearningDichotomies_C3F2/left_right_brain_2.jpg

Figure 1: Shows the different functions of the Left and Right sides of the brain.

Purpose of Study:

2.1 *Research Questions*

1. Do bilingual high school teenagers process sentences the same way as monolingual teenagers do?

2. Do bilingual high school teenagers process incoherent sentences differently than coherent sentences?

3. Do bilingual and monolingual high school teenagers understand the meaning of a sentence differently?

Methods & Materials:

3.1 *Participants*:

Six participants (5 female, 1male, and mean age- 17) were recruited from Briarcliff High School. All were right handed and had normal or corrected-to normal visual acuity with mostly no history of neurological insult or language disability. Figure 3 shows the language history of each of the participants and Figure 4 shows the neurological history of each of the participants.

Participant/Question	What language Were you exposed to as a child?	What language did you use as a child?	What language do you use now?
1	English	English	English
2	English	English &sometimes Spanish	English
3	English	English	English
4-Bilingual	Spanish & English	Spanish & English	Spanish & English
5-Bilingual	Spanish & English	Spanish & English	Spanish & English
6-Bilingual	Spanish & English	Spanish & English	Spanish & English

Figure 3: Language History. Shows what language the participants know and have learned in the past.

Participant/Question	Did you have any difficulties with speech, language and/or history?	Did you have any problems at school/academic problems?	What about attention?	Did you have any accidents or major illnesses?
1	Trouble pronouncing R	No	No	No
2	No	No	Sometimes	No
3	No	No	No	Brain Tumor
4-Bilingual	No	No	No	No
5-Bilingual	No	No	No	No
6-Bilingual	No	No	No	No

Figure 4: Neurological History. This shows if any of the participants used in the study had any neurological problems.

3.2 *Equipment:*

For my project I test the participants with an electroencephalogram (EEG). The electroencephalogram (EEG), a highly complex signal, is one of the most common sources of information used to study brain function and neurological disorders. An electroencephalogram (EEG) is a test that measures and records the electrical activity of the brain. Special sensors (electrodes) are attached to your head and hooked by wires to a computer. The computer records the brain's electrical activity on the screen or on paper as wavy lines.

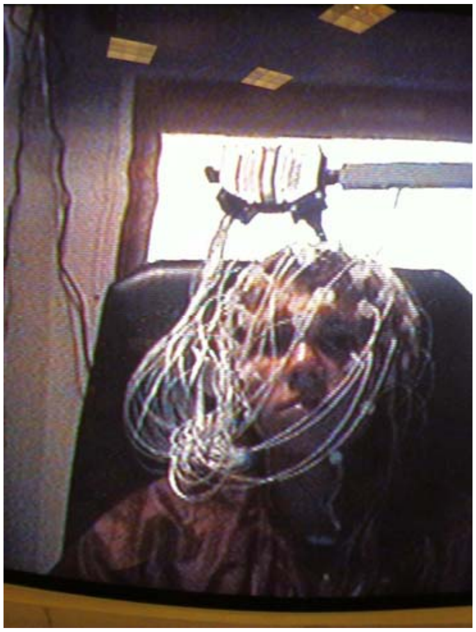


Figure2- Shows the electrodes in the EEG put on participants head.

3.3 *Electrophysiology*

Electrophysiology (ERP) is the study of the electrical properties of biological cells and tissues. ERP's were recorded to a frequent stimulus randomly replaced by three infrequent stimuli. Subjects received three different tasks. Each condition was divided into three blocks for a total of nine blocks. Subjects received breaks if needed. Subjects were instructed to pay very close attention to the sentences and all sounds during the study.

3.4 *Stimuli:*

First, the participant takes a Peabody Picture Vocabulary Test (PPVT) measures the receptive vocabulary for standard English .Once the participant passes the test the EEG is put on their head.

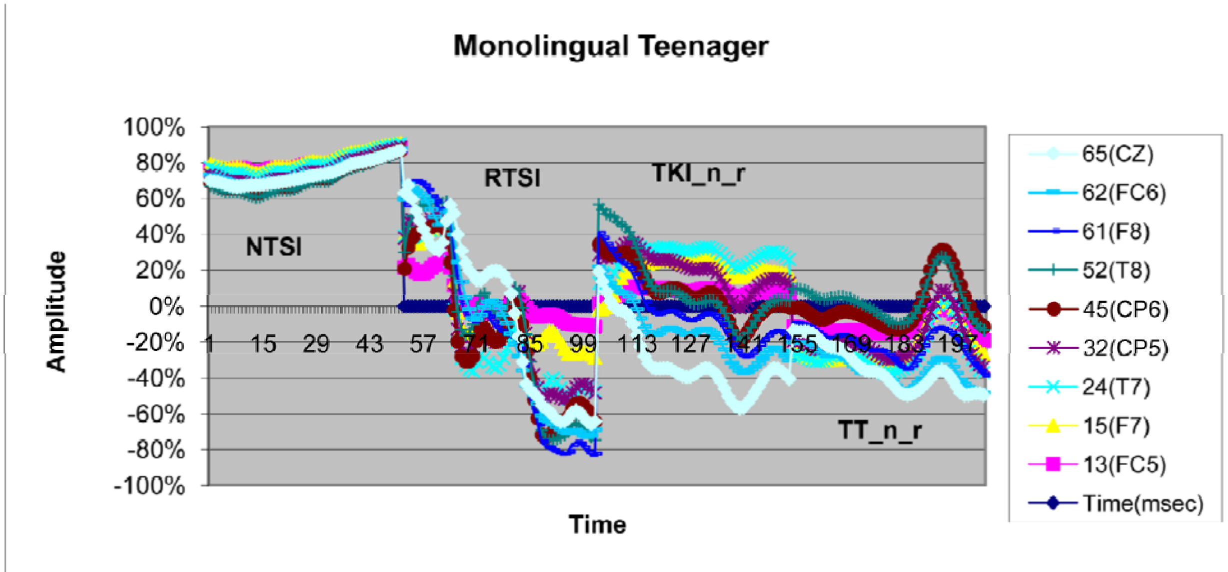
While the participant is taking the PPVT test, the EEG is getting soaked in water, a solution and baby shampoo. After the PPVT test, the EEG net is put on the participant. The net is put on in a back- and-forth motion. Once the net is put on the participant, the participant is put into a room and gets hooked onto the computer. First, I check if the impedance is fewer than 60 which is a control. On the computer there are two panels that show the brain waves of the participant. In the room there is a video camera and a microphone so that we can watch and hear the participant.

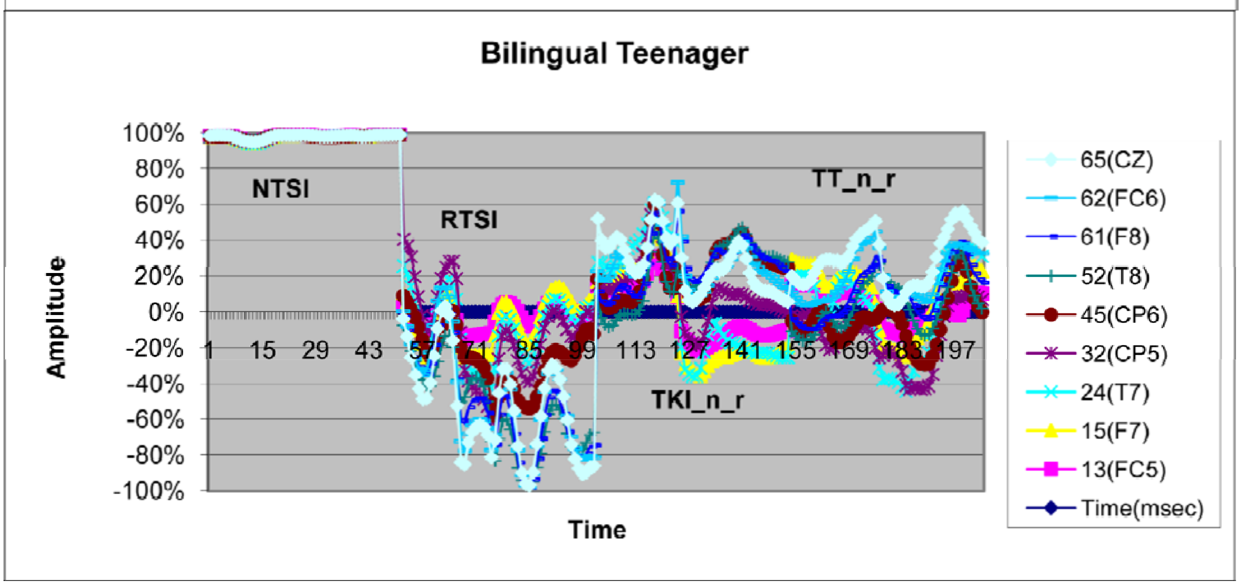
The first test that the participant does is the semantics study. This study shows pictures on the screen and the participant will hear two words after the picture is on. For example, they will see a picture of a book, and hear “book…desk”, or see “book”, and hear “car…noodle.” The participant does not have to do anything, just pay attention to the pictures and listen carefully. There are four short sets that each last less than three minutes. I tell the participant that I am watching them from outside and if they need us they can wave or speak up.

The second test that the participant does is the syntax study. The participant sees pictures on the screen of animals. While the picture is on the screen they will hear a sentence about the picture. They do not have to do anything; just look at the pictures, pay attention and listen carefully. This again will be four sets of pictures and sentences. Each set lasts three minutes.

The third test, which was the main test, participant does is the discourse study. The participant hears a story such as “One day, there was a boy named Tommy walking along Fifth Avenue. He walked into the toy store… At the end of the paragraph, they will hear a question such as “What did she see?” Then on the screen they will see pictures in the upper left, upper right, lower left and lower right corner (1, 2, 3, and 4). The participant must press a button on a panel and choose which one of the answers is correct. For this study, I do random sentences first and see how their brain responds to the sentences not being in order (incoherent). The second test is normal order, which is in coherent.

Results:





The graphs show that bilingual teenagers process incoherent stories, using all parts of their brain, differently than monolingual teenagers. NTSI symbolizes normal order of sentences in the story. For example: "Tommy went to the city and saw the Chrysler building, the empire state building and the Statue of Liberty. He was going to go to Times Square but there was a huge accident so he just stayed on 5th avenue." This story is in normal order and it makes sense because it is consecutive. RTSI is random order of sentences in the story. For example: "Huge accident, Chrysler Building, Statue of Liberty, stayed of 5th avenue, he was going to go to Times Square, Tommy went to the city." This sentence does not make any sense in the story so it is random order. The "nonsense" (TKI_n_r and TT_n_r) was processed differently by the monolingual and bilingual teenagers. For example: "ki po kop u ko pi ko." These are just random letters put together.

Figure 4 explains the different electrodes on the brain that stood out the most. Each site has a letter (to identify the lobe) and a number or another letter to identify the hemisphere location. The letters F, T, C, P, and O stand for Frontal, Temporal, Central, Parietal and Occipital. (Note that there is no "central lobe", but this is just used for identification purposes.) Even numbers (2, 4, 6, 8) refer to the right hemisphere and odd numbers (1, 3, 5, 7) refer to the left hemisphere. The z refers to an electrode placed on the midline. Also the smaller the number, the closer the position is to the midline. The numbers on the sides of graph 5 and 6 signify the position in were the electrodes are.

4.1 *Parts of the brain used for the study*

All of the odd numbers like 24(T7), 15 (F7), 13(FZ7) and 32 (CP5) are all part of Wernicke's area and Broca's Area. . Wernicke's area is the region of the brain that is important in language development. The Wernicke's area is located on the temporal lobe on the left side of the brain and is responsible for the comprehension of speech (Broca's area is related to the production of speech). Language development or usage can be seriously impaired by damage to the Wernicke's area. Broca's area controls facial neurons,controls speech production and understanding language.

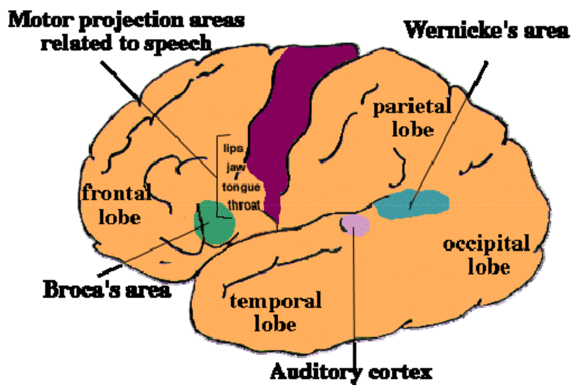


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Figure 1: Broca's area is in the lower part of the frontal lobe, and is involved in the formation of sentences, and Wernicke's area, located in the temporal lobe is involved in the comprehension of speech.

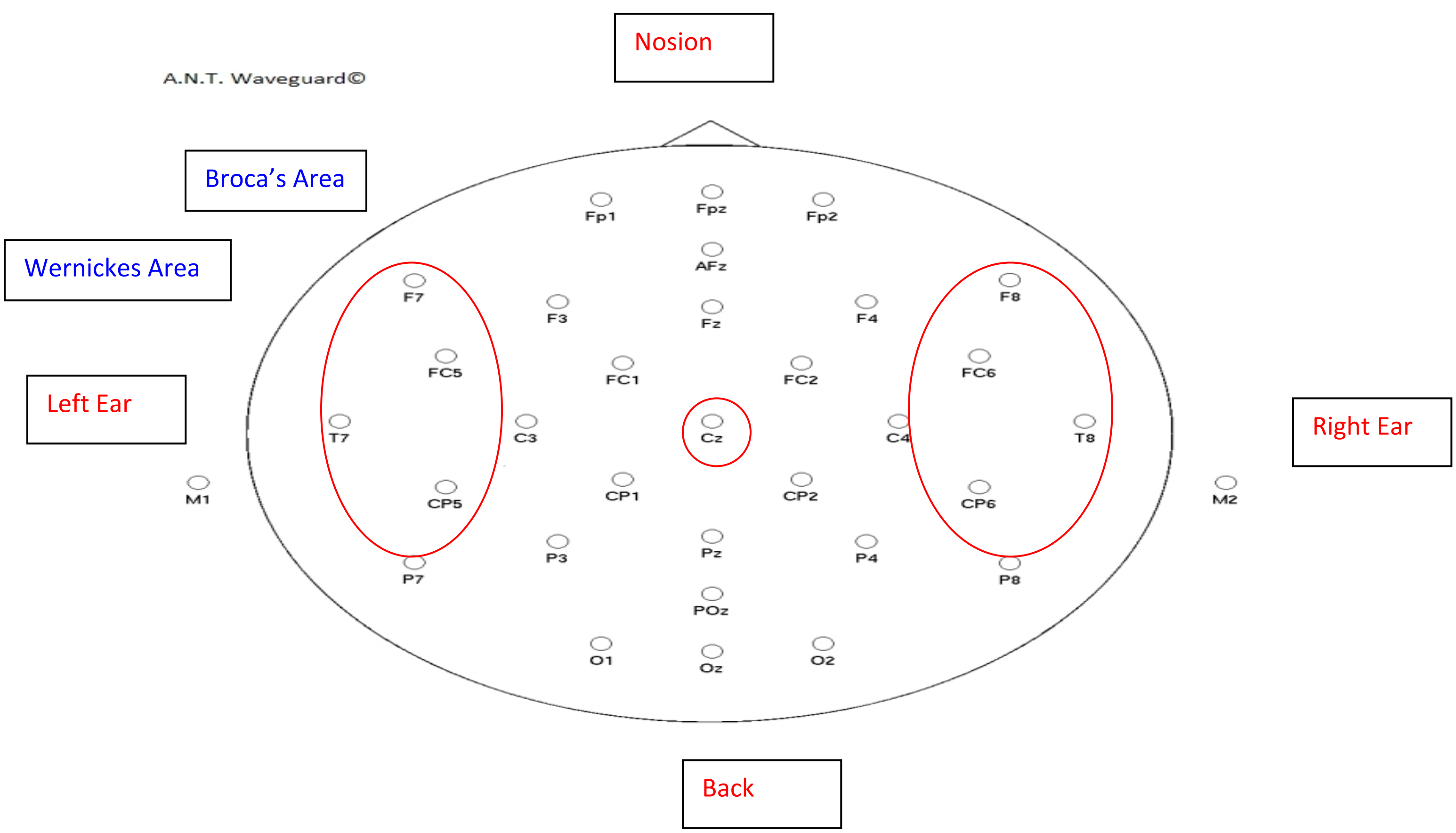

Figure 4: Electroencephalogram electrodes brain net positioning on the scalp. Red circles show the electrodes that show a positive result.

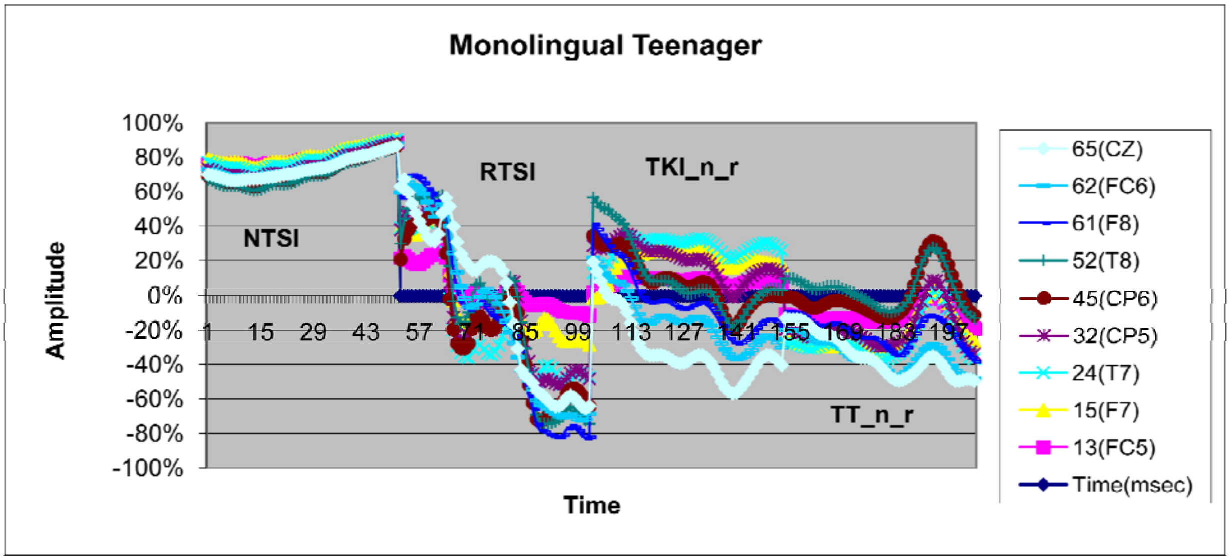

Figure 5: The figure above shows the brain waves of how a monolingual teenager processed the different tests.

4.2 *Monolingual Teenagers*

The graph above shows the average of three monolingual teenagers throughout the study. NTSI signifies how the participants process the story in coherent order. According to the graph, all of the parts of the brain worked similarly, by increasing, because the sentences made sense according to the order of the story. RTSI signifies how the participants process the story in an incoherent order. The different parts of the brain work differently because the story is incoherent. As shown in the graph, 61(F8), which is the blue line, the amplitude over time goes from the highest point to the lowest point. The granular frontal 61 (F8) is associated with reward, attention, long-term memory, planning, and selects sensory information (Fundamental Neuroscience). This means that as time passed the amplitude decreased. Also, at 24 (T7), the light blue line with tick marks, the brain processed the different sentences by decreasing over time. At 65 (CZ), which is the light blue line, the amplitude decreases then increases slightly and then decreases over time. CZ is located at the top of brain.

During the study, the participant had to listen to a story incoherently and coherently as well as "nonsense" which are a bunch of letters put together. The "nonsense" was in between the incoherent and coherent sentences. For example the participant would hear "ki po kop po ki" and the brain had to find the meaning of these letters. As shown on the graph of sections TKI_n_r and TT_n_r, there is a decrease and then an increase at time 195 in sentence processing with each part of the brain. The brain could not figure out the meaning to the letters and the participant could not understand the letters. 52(T8) increase drastically, 52(T8) is the part of the brain called the frontopolar, which plays a part in strategic processes involved in memory retrieval and executive function. RTSI all the parts of the brain are decreasing while in TKI_n_r the parts of the brain do not know how to process the information so it is all different.

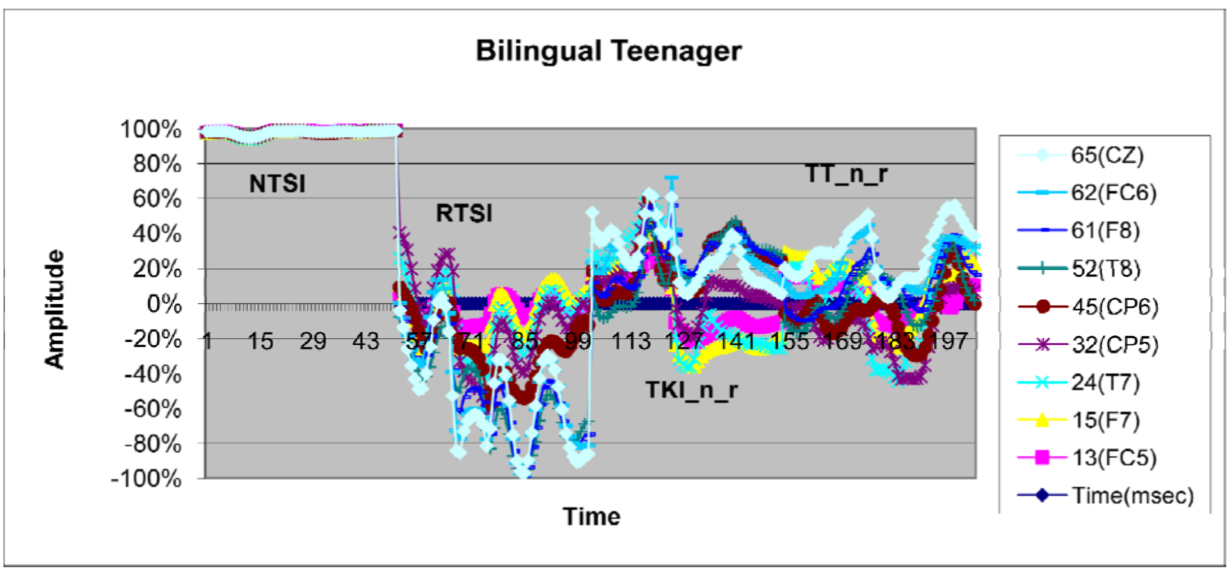

Figure 6: The graph above shows how a bilingual teenager processed the tests.

4.3 *Bilingual Teenagers*

The graph above shows the average of three bilingual teenagers throughout the study. NTSI is a story in coherent order. The bilingual teenagers processed the story using some of the parts of their brain with no differences. However, the RTSI study shows the parts of the brain that do not process the incoherent sentences. The sentences have meaning but the bilingual teenager has trouble processing what the sentences mean as a whole. 65(CZ) and 61(F8) increase and decrease several times as time passes. This means that the teenager had trouble understanding what the sentences actually mean. During the TKI_n_r and the TT_n_r the bilingual teenager had a hard time understanding the “nonsense” words such as “ki po ko pu ki”.It took the bilingual teenagers a longer time to process and it made them use every part of the brain differently. This is similar to how the monolingual teenagers processed the information.

Conclusion

I found that monolingual and bilingual high school teenagers process coherent sentences in a story similarly. The teenagers both use the same parts of the brain to understand the story. However, monolingual teenagers process differently incoherent sentences in a story. It takes the monolingual teenager less time to understand the story as a whole. Bilingual teenagers take a longer time to understand what incoherent sentences mean in a story. Both bilingual and monolingual teenagers understand the meaning of sentences; however they differ if the sentences are in a coherent or incoherent order in a story. My future research would involve testing middle school students ages 9-12 to see how their brain waves compare to those of the high school students. It would be interesting to see how age acquisition affects brain waves and understanding of incoherent and coherent stories.

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