Interhemispheric and gender difference in ERP synchronicity of processing humor

Calvin College
Abstract

This study investigated the difference in hemisphere synchronicity, measured by EEG during a humor processing task, between males and females, and also between jokes that end with proper joke, non-joke, or filler endings. We hypothesized that females would show higher average synchronicity than males across the types of joke conditions, and that the joke condition would show the highest synchronicity, compared to the non-joke and filler conditions. We showed 35 undergraduate students (17 males and 18 females) from introductory psychology classes set up line of “one liner” jokes and then gave either a joke ending, an expected, filler ending, or an unexpected non-joke ending, while measuring their EEG recordings. The data was analyzed using independent sample and paired sample t-tests. Results showed that females had higher average synchronicity than males, $t(33)=2.086$, $p=0.047$. They also showed that in the joke condition, the participants had the lowest average synchronicity scores, $t(34)=3.061$, $p=0.004$, $t(34)=2.539$, $p=0.016$. Possible explanations for these results are discussed.

Keywords: Interhemispheric transfer; Joke comprehension; Gender; Hemisphere specialization
Interhemispheric and gender difference in ERP synchronicity of processing humor

**Interhemispheric specialization in language processing**

Previous studies have revealed that the right and left hemispheres differentiate in specialization of processing of language; for example, looking at studies of brain damage to the left hemisphere, deficits in speech production, naming, and language comprehension can be observed (Blumstein, 1994; Damasio, 1992). Furthermore, left hemisphere damage is connected to dramatic linguistic deficits, which are not observed in lesions to the right hemisphere; however, right hemisphere damage is linked to exhibition of deficits in subtle semantic and pragmatic processing, an example being comprehending familiar idiomatic phrases (Van Lancker & Kempler, 1987), metaphors (Brownell, 1988), and indirect requests (Stemmer, 1994; Stemmer, Giroux, & Joanette, 1994). These studies indicate how basic language expression and understanding is associated with the left hemisphere, while the right hemisphere is responsible for perceiving and using background knowledge and recognizing the connection between a saying and its context. Understanding idioms, metaphors, indirect requests, and other more subtle forms of language would require the skill to identify the conditions and the framework in which the communication took place.

**Interhemispheric specialization in relation to humor**

Understanding humor, or processing a joke, is an example of such language comprehension that utilizes previous knowledge of context, which, as previously mentioned, is processed by the right hemisphere. This is illustrated in Brownell, Michel, Powelson, & Gardner’s study (1983) of how damage to the right hemisphere impairs the ability to understand
jokes. Joke comprehension, as well as the ability to create jokes, indicates mastery over not only
the mechanisms of a language, but also the context in which the joke was made. However, the
right hemisphere is not solely responsible or only involved in the comprehension of jokes; the
left hemisphere is involved as well. Goel & Dolan (2001) shows this in their event-related
functional magnetic resonance imaging study, where they compared how understanding semantic
jokes to a nonjoke baseline resulted in increased activation in RH Brodmann’s area 21 and LH
areas 21 and 37. As this study demonstrates, the two hemispheres seem to be working together to
help an individual comprehend humor as indicated by elevation in activity levels of both
hemispheres.

**Role of corpus callosum in interhemispheric communication**

Since the two hemispheres seem to be working together, it would make sense to look into
a structure that facilitates the communication between the left and right hemispheres. The corpus
callosum acts as such a bridge; it is a band of nerve fibers comprised of over 190 million axons
that transfer information between the two cerebral hemisphere of the brain (Schoenemann,
Chechan, & Glotzer, 2005). In the first months of prenatal development, the corpus callosum of
some individuals may be absent or fail to cross the midline to the opposite hemispheres – this is
the birth defect known as agenesis of corpus callosum (Rakic & Yakovlev, 1968). Although
individuals with agenesis perform normally on many standardized tests, they have difficulty
processing non-literal language such as proverbs and semantic humor (Brown, Paul, Symington,
& Dietrich, 2005). The results of these studies demonstrate how information from both
hemispheres need to be joined to fully understand semantic humor.

**Past studies involving ERP and N400**
Our current study proposes to investigate more deeply how the two hemispheres work together. Specifically, we will be comparing how left and right hemispheres react to jokes. For this, it is necessary to gain a thorough understanding of how Coulson & Williams (2004) carried out their study of joke endings using event-related potential. The start of a joke begins with a certain context, the “set-up”. An example is “the substitute player hit a home run with my…”, in which the context would be the athletic field. Upon hearing how the joke ends, or the “punch line”, the mental set must shift (Coulson & Williams, 2004). To finish the previous example, the punch line would be as following: “The substitute player hit a home run with my…wife”. The context of the joke now has shifted from sports to romantic relationships. Coulson & Williams (2004) terms this shifting of context frame-shifting. This would not occur if a filler ending that was expected completed the sentence: “The substitute player hit a home run with my…bat”.

Another potential ending would contain the unexpected surprise element, but not require the frame-shift; this would be considered a non-joke ending. The following sentence ends in such a punch line: “The substitute player hit a home run with my…uniform”. Although the ending word is unexpected, the context of sports still remained. Coulson & Williams (2004) examined brain electrical activity during this frame-shifting through EEG – they specifically looked at the N400 wave, which is the small dip in the wave between 300-500 msec that occurs when individuals experience an unexpected or surprise ending to a sentence. They found that there was a greater difference between joke and non-joke N400 in the left hemisphere compared to the right hemisphere, which indicates that left hemisphere, which processes language in a more literal sense, finds processing the joke ending more difficult. On the other hand, the right hemisphere,
which processes nonliteral language, seems to find processing the joke endings not as difficult, and actually regards the joke endings with the same ‘surprise level’ as the non-joke endings.

Current study

Now that the disparity in N400 waves of right and left hemisphere has been confirmed, our current study aims to investigate the correspondence, or the ‘synchrony’ of this wave – the correlation of the up-down patterns. This measure of synchrony was adopted from Jerger, Martin, & McColl’s study (2004). They compared twins, one of whom had an auditory processing disorder, which they believed was due to an impaired interhemispheric communication via corpus callosum. Through EEG recording devices, they discovered that the event related potentials between the two twins indicated a difference in the synchronicity of the waves – more specifically, the waves of the twin with the healthy corpus callosum were more synchronized than her sibling with the impaired corpus callosum.

The corpus callosum, as shown by the previous study, is an important structure in contributing to the two hemispheres working together. The significance of the corpus callosum in interhemispheric communication is demonstrated in another study by Moes, Brown, and Minnema (2007), in which they examined gender differences in interhemispheric transfer time. Females had a greater speed of right-to-left transfer of language information, and are also known to have a thicker corpus callosum and greater bilateral representation of language – this explains gender differences in certain skills, like the advantage that females have over males in verbal fluency and memory.

In our study, we will repeat the basic procedure of Coulson and Williams (2005), with the addition of central word presentation and added pictures. Our hypothesis is that we will see
the highest average left-right “synchrony scores” for the joke condition, compared to the non-joke and filler endings, because previous findings suggest that the two hemispheres need to coordinate and work together to complete the task. Also, based on the study by Moes, Brown, and Minnema (2007), we hypothesize that females will show higher average “synchrony scores” than males despite the type of conditions – joke, non-joke, or filler endings.

Method

Participants

Thirty-nine participants were drawn from students in an introductory psychology class and received partial credit towards a course requirement for participating in the experiment. All participants signed a consent agreement before participating. Data from two participants were not used because they could not be read. An additional two participants’ data were not used because at the time of the recording, the ERP was not detected due to technical problems. This brought the total number of participants to thirty-five, comprised of eighteen females and seventeen males.

Design & Procedure

Participants were connected to a continuous 16-lead EEG cap and the activity recorded using a EPA-6 Electro-Physiology amplifier (Sensorium, Inc), amplified 20,000 X and filtered at 0.5 – 50 Hz. All tests were run with impedance levels kept below 5k(omega); sampling rate was 1 kHz.

The participants were given verbal instructions by the researcher about what was expected of them in participating in the study. The participant was equipped with headphones
and seated in front of a computer. The set up line to a joke was read to them by a pre-recorded female voice.

The set-up line was always followed by a joke, non-joke unexpected, or a filler ending. The joke ending required a shifting of the mental set, while the non-joke unexpected ending only contained the surprise element, but not require the mental set shift. The filler ending was an expected word. An example of the joke ending to a set-up line such as “the substitute player hit a home run with my…” would be “wife”; this shifts the context of the joke from sports to romantic relationships. An example of a set up line completed with a non-joke unexpected ending would be: “The substitute player hit a home run with my…uniform”. ‘Uniform’ is an unexpected word, but still keeps the context within the playing field. If the set-up line was completed with a filler ending, it would resemble this phrase: “The substitute player hit a home run with my…bat”. The word ‘bat’ is an expected ending and does not introduce a surprise element or require a frame-shift.

The set-up line to the jokes, non-joke unexpected, or filler sequences had been previously tested for funniness by the use of a survey. The survey asked students in a lower level psychology class to rate, on a scale of 1-5 (1 – not at all funny; 5 – very funny) whether or not they found the joke to be funny. From the results of this study we selected the twenty items that were rated as the funniest. Also, from this survey, we were able to determine that the joke endings were constantly rated as higher in funniness than both the non-joke unexpected and filler endings.

The joke was heard in both ears simultaneously to promote both left and right hemisphere stimulation. For the duration of the time when the joke was being heard in the headphones, a
corresponding picture on the screen was simultaneously displayed to maximize the mental set for anticipating the most likely outcome to the joke. Upon completion to the joke being heard, the picture displayed on the computer disappeared and was replaced by a small x in the center of the screen that visually oriented the participant to where they should look. The x was displayed on the screen for a period of 150 milliseconds. The x then disappeared and was replaced by either the joke ending, the non-joke unexpected ending, or the filler ending. The end to the joke was presented visually in the center of the participant’s visual field. The resolution to the joke was always one word, which was presented for a duration of 200 milliseconds. All joke endings were semantic as compared to phonological (puns).

The participants were given a total of 180 trials; with 60 of the trials having joke endings, 60 of the trials having non-joke unexpected endings, and 60 of the trials having filler, the coherent and not surprising endings. After the participant had seen the set-up line and the ending, he or she was asked to assess whether the trial was a joke or a not. The participant did this by pressing number 1 on a keyboard to indicate that the ending was a joke word and the number 2 to indicate that it was not a joke word. The trials were given to participants in blocks of 60, with the opportunity for the participant to take a break and indicate that they were ready to proceed testing again by pressing the space bar. Upon completion of the test, the participant was debriefed about the purpose of the test and told of their right to review the data after it was gathered.

The two independent variables were gender and the joke ending conditions. We performed a 2-tailed independent samples t-test to determine whether there was a significant difference between the synchrony scores of males and females. To determine the differences
between the synchrony scores of joke condition and non-joke condition, and the joke condition and the filler condition, we performed 2-tailed paired samples t-test for each pair. We also performed a 2-tailed independent samples t-test to determine whether there was a significant difference between the synchrony scores of males and females in the anterior, middle, and posterior locations of the brain. Although this was unrelated to our hypothesis, we performed this test to add depth in analysis of the gender differences.

**Results**

Event related potentials (ERPs) were gathered from segmented EEG, corrected and artifact free trials only, from 300-500 ms after the final world display. The higher the IHSS, the greater the level of synchronicity between the two hemispheres. The averaged ERP IHSS across all 16 leads were analyzed using independent samples t-test for the gender hypothesis and paired samples t-test for the joke ending conditions hypothesis. The time segment that was run between 300-500 milliseconds will be referred to be as the n400 segment.

There was a significant main effect in gender \([t(33)=2.086; \ p=0.047]\) with woman (M=0.6582, SD=0.08540) having higher IHSS across all the joke conditions, than men (M=0.5962, SD=0.09192). This was predicted in light of the study by Moes et al. (2007). There was also a significantly higher IHSS in the non-joke unexpected condition as compared to the joke IHSS \([t(34)=2.539; \ p=0.016]\) (figure 1). The filler condition also exhibited a significantly higher IHSS compared to the joke condition \([t(34)=3.061; \ p=0.004]\) (figure 1). This was contradictory to our hypothesis.
There was also a significantly higher IHSS in the middle region of the brain of females, compared to the males \([t(33)=3.083; p=0.004]\) (figure 2). However, there was no significant difference in IHSS between females and males in the anterior and posterior regions of the brain.

**Discussion**

Based on previous studies done on the difference in interhemispheric communication between genders (Moes, Brown, & Minnema, 2007) and synchrony scores (Coulson & Williams, 2004), we hypothesized that females would show higher IHSS than males, and that in the joke condition, the highest average left-right IHSS would be observed. This was partially supported by the results; main effects were found in gender regardless of the conditions – joke, non-joke, or filler endings, which is consistent with previous research and a part of our hypothesis. As Moes, Brown, and Minnema (2007) demonstrated in their study, females have a greater speed of right-to-left transfer of language information, a thicker corpus callosum, as well as greater bilateral representation of language than males. Our data replicated their findings.

However, we found higher IHSS for the non-joke unexpected endings and filler endings compared to the joke endings, which was contrary to the other half of our hypothesis, that in the joke condition, the highest average left-right IHSS would be observed. A possible explanation for this may be that in the joke condition, which is more difficult to process than the non-joke or filler conditions, the right hemisphere may be inhibiting the left hemisphere, thus leading to a lower IHSS score. We had had previously suggested that the two hemispheres would need to coordinate and work together to complete the task, as Goel and Dolan (2001) established in their study. However, this may only be the case for filler and non-joke conditions; because processing these tasks does not require mental set shifts, the left hemisphere would be as able as the right
hemisphere in its processing speed or efficiency. Thus, the two hemispheres may be working better together, with no inhibition occurring. However, in the joke condition, because the right hemisphere specializes in processing nonliteral language, as Brownell, Michel, and Powelson (1983) show in their study of damage to the right hemisphere, it seems to process joke endings with more ease than the left hemisphere. Because the left hemisphere processes language in a more literal sense, the right hemisphere may be inhibiting the left hemisphere from participating in the processing of the joke, possibly to increase efficiency and decrease the cognitive energy load – hence, the lower IHSS for the joke condition compared to the others. Future research could confirm this line of thought and investigate whether inhibition really does exist, and if it does, the extent to which the right hemisphere suppresses the left hemisphere.

Another interesting finding was the difference in IHSS for the genders, when the distinct locations of the brain – anterior, middle, posterior, to be exact – were taken into account. There were no significant difference in IHSS between females and males in the anterior and the posterior regions of the brain. However, females exhibited a significantly higher IHSS in the middle part of the brain. This may be related to the close proximity of language processing regions such as Wernicke’s area or Broca’s area. This finding could provide a direction to take the study further, and investigate what underlying differences in the middle area of the brain between male and female would result in a significant difference in IHSS, compared to other regions of the brain.

The results of this study and possible future findings may help extend our knowledge of how the brain processes humor and other nonliteral language, and give insight to how individual differences, such as handedness, may play a role. For example, many comedians are known to be
left-handed, which may be explained by increased inhibition activity by the right hemisphere, resulting in an increased ability to process, and possibly create humorous jokes. Also, expanding our awareness of how interhemispheric processing works may help us better understand individuals with disorders such as autism, Asperger’s syndrome, agenesis of the corpus callosum, and non-verbal learning disorders.
References


Figure 1. IHSS scores by varying conditions.

Figure 2. IHSS scores by gender and varying brain areas.