UNIVERSITY OF GLOUCESTERSHIRE

Can you see what I am saying? Investigating the differences in processing of onomatopoeia and nouns with a behavioural study and EEG case study

Elise Denton

Supervised by: Dr Dianne Catherwood

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ABSTRACT

This current research aimed to investigate the differences in processing of onomatopoeia and nouns. The first independent variable was modality (written, auditory) which was conducted using a between-subjects design whereby participants were allocated to either one of these conditions. The second IV was type of associated word (onomatopoeia, nouns) which utilised a within-subjects design with each participant being exposed to each type of word. A mixed effects Analysis of Variance (ANOVA) was conducted to investigate whether these effects were statistically significant. This indicated that there was not a significant difference between words recalled when modality and type of associated word were manipulated. An electroencephalogram (EEG) was conducted to further investigate and examine the neurological regions involved in the processing of these two categories of words. Results indicated that the brain regions most active when encoding and recalling onomatopoeia and nouns were different as well as the 'spread of activation'.

KEY WORDS:	ONOMATOPOEIA	ELECTROENCEPHALOGRAM	NOUNS	MODALITY	RECALL

Contents

Introduction

Do people see what they say? When we are conversing with people do we experience some form of mental imagery? It would be plausible to assume that people paint a mental picture of what they are saying or what they are interpreting as a method of increasing their understanding of it.

A lot of research has been conducted into how words are processed and which regions of the brain are used in doing so. However are different types of words processed differently within the brain? In this piece of research I will attempt to answer this question in relation to the processing of onomatopoeic words and how this may differ compared to the processing of nouns. Language comprehension and speech production have been the focus of many years of research, with these abilities being localised to certain regions of the brain using imaging techniques. These language centres identified are known as the Broca's region which has the basis for the production of language (Purves, et al., 2008). Brodmann area (BA) is a method which maps the cortex of the brain based on the cell structure; all areas are differentiated from one another due to distinct features (Reber, 1985). Broca's region can be found in BA 44 and 45 (Banich & Compton, 2011). A second language centre in the brain has been identified as the Wernicke's area. This has been associated with the comprehension of both written and spoken language and is located in BA 22 (Purves, et al., 2008). A particular focus will be taken upon the Wernicke's region of the brain as this is involved in comprehension of language which is a key region of the brain in understanding how words of processed. BA 22 contains the posterior superior temporal gyrus (STG) (Kober, Moller, Nimsky, Vieth, Fahlbusch, & Ganslandt, 2001) which has been cited as being involved in auditory processing which includes the processing of language (Bigler, et al., 2007).

Onomatopoeia can be defined as words which imitate the thing being named e.g. *drip* and *bang* (Reber, 1985). The processing of different words has been widely investigated using neuroimaging techniques but very little research has been conducted into the area of onomatopoeic words and which regions of the brain are used to process them. After conducting a thorough literature review only one piece of research directly related to the neural mechanisms used in the processing of onomatopoeia was found. Hashimoto, Usui, Taira, Nose, Haji & Kojima, (2006) used an event related fMRI (functional magnetic resonance imaging) technique to investigate the neural processing of onomatopoeia. This technique measures changes in neuronal activity based upon changes in physiology such as cerebral blood flow and blood oxygenation and this is then used to infer the changes in activity levels of brain regions (Banich & Compton, 2011). By comparing nouns (verbal), animal sounds, pure tone and onomatopoeia they were able to produce imaging data which highlighted which regions of the brain were active when being exposed to each stimuli. Nouns produced activation in the bilateral middle and anterior superior temporal sulcus (STS) and the left anterior STS/STG. Onomatopoeia was shown to activate extensive regions of the brain such as the left anterior STG, bilaterial middle and anterior STS and the bilateral inferior frontal gyrus. The regions activated when been presented nouns and onomatopoeia were similar with onomatopoeia sounds activating more extensive regions. As an adaptation to further this study I aimed to explore a number of different aspects which could impact upon the processing of onomatopoeic words and nouns. This adaptation would allow for the investigation of variables (modality and associated word) which may influence the processing of onomatopoeia while also researching the brain regions associated with the encoding and retrieval of these words using an EEG and behavioural study.

Certain regions of the brain have been widely associated with language production and comprehension (Purves, et al., 2008). But are all words processed in the same way using the same brain regions or do these differ between types of word presented. Viglicocoo, Vinson, Druks, Barber & Cappa, (2011) state how there has been an increase into research investigating whether words with different grammatical classes are processed differently. This has led to the production of different results and conclusions with the main arguments being that nouns and verbs are processed in partially different neural networks and that the neural differences found are not related to the word but instead what the word refers to (action v object). Neuroimaging studies have suggested different brain networks are used in the processing of different word classes such as nouns and verbs (Federmeier, Segal, Lombrozo, & Kutas, 2000). Research has been conducted into the neural processing of words, Khader & Rosler, (2004) investigated the differences in processing of visually presented nouns and verbs using EEG (electroencephalograph) data. Differences in the processing were found in the inferior frontal gyrus and BA 45.

Halsband, Mueller, Hinterberger, & Strickner, (2009) found that the learning of high-imagery words led to increased activation in the occipital cortex and prefrontal areas and that improved memory performance is associated with high-imagery words. Each noun used in the study was chosen based on an imagery rating but this was not possible for the onomatopoeia words. The output of imagery rating for the nouns may lead to increased activation and ultimately recall of these words compared to onomatopoeia.

The second IV of this study is modality which is defined as the sensory system to which a stimulus is presented (Reber, 1985). The presentation of onomatopoeia and nouns can be manipulated to enable the investigation of whether the sensory system to which they are presented has an effect on recall. Auditory systems will be used for one condition whereby the words are presented using a dichotic listening task. Dichotic listening tasks have been used in many areas of research in psychology. There has been a vast amount of literature published citing a right ear advantage (REA) in dichotic listening tasks (Thomsen, Rimol, Ersland, & Hugdahl, 2004; Hugdahl, Westerhausen, Alho, Medvedev, & Hamalainen, 2008). There have been numerous explanations offered to explaining this finding with Sætrevik, (2012) attributing this advantage to the processing of language stimuli being lateralised to the left hemisphere. Hiscock, Inch, & Kinsbourne, (1999) conduted a dichotic listening task whereby attention instructions were given to participants, this was shown to have no effect on detection of the target word and a REA was still apparent. To avoid the possibility of a REA affecting results found in the dichotic listening task a control method was used. Each word pair contained a target word (random word) and either onomatopoeia or a noun. The presentation of the target word was counterbalanced while participants were not aware which ear this word would be presented to, this enabled the control of attention and reduction of any REA.

Auditory selective attention has been studied in great depth as a method of understanding how attention is allocated when processing audio stimuli and how this may relate to a REA (Hiscock, Inch, & Kinsbourne, 1999). According to Kinsbourne's, (1970) model of selective attention bias, a greater level of activation is shown in the contralateral hemisphere to which the stimulus is being presented. Great support has been shown for this model of selective attention with Alho, Salonen, Rinne, Medvedev, Hugdahl, & Hämäläinen, (2012) reporting that selective attention during a dichotic listening task indicates stronger processing of sounds in the auditory cortex contralateral to the attended direction. Using a condition whereby participants were instructed to attend to stimuli presented to the left ear it was found that the REA could be minimised.

During a dichotic listening task and visual paired words task attention is a particularly important phenomena in helping to understand why certain words are remembered and others are not. Many models have attempted to explain how attention is allocated to incoming information (Groome, Dewart, Esgate, Gurney, Kemp, & Towell, 1999). The attenuation model (Treisman, 1964; cited in Groome, et al, 1999) proposes that we do not filter information which involves processing some of the information and not the rest but rather we process all information but at differing levels. The model contains a 'non-attended channel' which attenuates incoming stimuli. Attenuation is a term used to describe the reduction in strength, intensity and volume of a stimulus (Reber, 1985). This model suggests that when a person is completing a dichotic listening task or visual task all the information that is presented to them will be processed but this will be done at a different level, with some stimuli having greater strength of processing and attention allocated to it than another stimuli presented to a different channel. For example in a dichotic listening task each word is presented to a separate ear at the same time but according to this model the level of processing for one ear will be reduced rather than stopped and the stimuli presented to the other ear will be fully processed. Using recognition as a method of recall rather than free recall may lead to an increased number of words being recalled as there is an active cue.

Word frequency and familiarity have also been demonstrated to have an effect on results found in recall studies but these factors are often seen not to be considered when conducting a dichotic listening task (Techentin & Voyer, 2011). Words for dichotic listening tasks are often chosen on the basis that they 'fuse' together so that when the dichotic listening task is being conducted and the two words are presented simultaneously the participant is only able to attend to one of the words (Techentin & Voyer, 2011). Using this information the words in this study were not chosen based upon how well they 'fuse together' but rather on a number of different criteria such as number of syllables, number of letters, imagery rating, concreteness and meaningfulness (Paivio, Yuille, & Madigan, 1968).

The auditory system of the brain is a very intricate system containing numerous interconnected elements. The primary auditory cortex (BA 41) is located along the mediolateral axis of the Heschl gyrus (Morosan, Rademacher, Schleicher, Amunts, Schormann, & Zilles, 2001). A further region of the brain associated with the processing of sounds is the secondary auditory cortex (BA 42). A key component of the secondary auditory cortex is the superior temporal gyrus (Tsunada, Lee, & Cohen, 2011) which is associated with also associated with BA 22.The superior temporal gyrus is deemed to be a main anatomical substrate for speech, language and communication (Rajarethinam, DeQuardo, & Tandon, 2000). As demonstrated by Bigler, et al (2007) BA 22 is associated with auditory and language processing. BA 22 contains the superior temporal gyrus which has been extensively linked with activation when completing auditory and linguistic tasks (Morosan, Schleicher, Amunts, & Zilles, 2005).

Through investigating auditory and language systems within the brain it allows for greater knowledge to be gained about how these systems work as well as what happens when a problem occurs such as damage to the regions after an accident or trauma. This information can be invaluable in helping a person to overcome such an issue as it can then be understood which systems are not working correctly and different strategies can be adopted to help overcome some issues which may be faced. It is hypothesised that these regions identified by Morosan, et al, 2001; Tsunada, et al, 2011; Rajarethinam, et al, 2000 will have been activated during the EEG study when processing onomatopoeic words due to auditory components associated with this type of word.

The use of neuroimaging techniques such as EEG enables the study of the brain in great detail to allow the localisation of functions to specific regions of the brain. Research has been conducted into the brain regions which are associated with the processing of language and how the regions can sometimes differ depending on the type of word being presented. Auditory systems in the brain have also been identified and researched using a variety of different methods. Sharda, & Singh (2012) are among some of the researchers to investigate the phenomena of auditory perception. Using an fMRI machine auditory perceptions of natural sounds were examined, there were three categories of words, animal sounds, environmental sounds (river) and human vocal non-speech sounds (laughing). Results indicated increased levels of activity in the primary and secondary cortices as well as in the insula, parahippocampal gyri and motor cortices. The findings relating to human vocal non-speech sounds could be related to the proposed study of onomatopoeia as the processing of these types of words may vary depending on whether it is perceived as a word, sound or both so extensive regions of the brain should be activated (Hashimoto, Usui, Taira, Nose, Haji, & Kojima, 2006).

Memory will be a key aspect relating to the current study as the DV is the number of words correctly recognised as a method of investigating recall. Baddeley & Hitch (1974) proposed a memory model which was termed the working memory model. The model considered working memory as a place where information is analysed and processed (Groome, Dewart, Esgate, Gurney, Kemp, & Towell, 1999). Performance of two tasks which are similar in content were severely disrupted as they were competing for limited processing capacity, which could be true with the dichotic listening task so participants who have the stimuli presented aurally may perform poorer than if the stimuli were presented visually. Rummer, Schweppe, Fürstenberg, Seufert, & Brünken, (2010) investigated how modality presentation influences working memory with the conclusion that visual texts use the same working memory subsystem to pictures whereas auditory texts require additional cognitive resources.

Memory models and allocation of attention have been linked in the academic literature due to the intrinsic nature of the two models. Short-term memory (STM) is the memory for information which has received very little processing or interpretation, it is said to have a very limited capacity (Reber, 1985). Stimuli and material are hypothesised to be held in the STM store through rehearsal. Broadbent (1957) has produced many models which are used to explain the allocation of attention and how memory in interlinked with this. He states that if two stimuli are presented at exactly the same time they will become ‘jammed’ leading to inadequate processing of these stimuli which is shown when tested using immediate recall, this effect may be reduced if delayed recall is tested. However, if the two stimuli are presented not entirely simultaneously then the first stimuli to arrive will have an advantage in the allocation of attention and will be processed at greater depth. As part of the behavioural study the modality of stimulus has been manipulated so that it will either be presented through a dichotic listening task or through a written PowerPoint presentation. For both modality presentations the stimuli (onomatopoeia and nouns) will be presented at the same time which may lead to the incomplete or reduced processing of one of the stimuli for both the visual and audio condition of the main experiment.

A decision was made for the paired random words to be recalled rather than the onomatopoeia or noun. This was chosen because more focus may be put upon the onomatopoeia than the noun due to the uniqueness and lack of familiarity associated with onomatopoeia as the nouns are more commonly used in language. Paired-associative learning is a technique used whereby two words are presented simultaneously which will both be processed and one word will then be recalled (Reber, 1985). The current study is a variation of this technique whereby both words will be presented either through audio or written methods and then one of the words will be recalled but the target word of interest in the other word in the pair. Results from the recall of the random word will be used to imply how the other word (onomatopoeia/nouns) was processed. Schmidt, Krause, Mottaghy, Halsband, Herzog, Tellmann, & Müller-Gärtner, (2002) conducted a paired-associated learning task with the stimulus being presented both aurally and visually, while also taking into account brain activation using a PET (positron emission tomography) scan. It was found that extensive brain regions were activated regardless of the presentation modality.

Cognitive load of a task is defined by the proportion of time in which it captures attention which can hinder the ability to attend to other demanding tasks (Barrouillet, Bernardin, Portrat, Vergauwe, & Camos, 2007) can be increased by completing two tasks of the same nature at the same time. It is theorised that this is due to the limited processing capacity of the short-term and working memory (Groome, Dewart, Esgate, Gurney, Kemp, & Towell, 1999). This means that by performing a dichotic listening task whereby two words are presented at the same time this may increase cognitive load which will reduce the person’s ability to actively attend (Dittrich & Stahl, 2012) to both pieces of information as presented in Broadbent’s model of memory (1957) and may ultimately lead to reduced recall of words presented through auditory modality. Underwood (1973) also states that during a dichotic listening task there is the possibility that a person’s processing capacity may be allocated to one of the channels meaning that the words processed in the other channel will have limited processing capacity. Onomatopoeia may be shown to produce more of a limit on working memory capacity than nouns due to a number of different factors. One such factor could be familiarity as nouns are commonplace in everyday vocabulary whereas onomatopoeia are not considered to be such and familiarity can be demonstrated to have an effect on recall, but it may be difficult to determine how familiar words are to certain people. (Carlson, 1954). Another factor to be considered would be the type of word that onomatopoeia is in that it is a word sound which could lead the activation of a number of different brain regions which could ‘slow’ the processing speed of these words.

There are two IV’s with two levels in this current study. IV 1 is modality (audio and visual) and IV 2 is type of associated word (noun and onomatopoeia). The DV of the current study is number of words recalled in a recognition task. Based on a thorough literature review regarding the way in which onomatopoeia words and nouns might be processed in working memory, I have generated two hypotheses that will be tested. A main behavioural study was designed to investigate the effects of the IVs on recall of paired words while supplementing this with a small scale case study involving two participants. A small scale case study was conducted due to time constraints and participant availability.

Hypothesis 1 – When random words are paired with onomatopoeia and nouns the random words paired with onomatopoeia will be recalled at a lesser rate than the random words paired with common nouns. In a paired learning recall task the type of associated word will have a significant effect on recall with words being paired with onomatopoeia being recalled at a lesser rate than those words paired with nouns.

Hypothesis 2 – Onomatopoeia will be processed neurologically differently to nouns when data are collected using an EEG machine. Onomatopoeia is expected to engage more extensive regions of the brain including Brodmann areas 17, 41 and 42.

Hypothesis 3 – It is hypothesis that when modality is manipulated this will have a significant effect on the recall of words in a recognition task.

Behavioural study: Method

Participants

Participants were both students and non-students and were recruited using an opportunity sample. An opportunity sample was used as the effects being researched should be apparent in the general population and the sample was readily available. Participation was entirely voluntary with informed consent being gained from each participant. As part of the consent form each participant was asked if they would be prepared to take part further in the study which would involve collecting data using an EEG machine. 64 participants would be needed for each condition to show significant differences using a medium effect size (Cohen, 1992). However, due to time constraints for the written condition of modality 16 participants were recruited (12 females, 4 males, mean age = 22.63 years, SD = 8.29 years) and for the auditory condition 15 participants were recruited (9 females, 6 males, mean age = 28.40, SD = 14.41 years).

Design

The study conducted used a mixed effects design containing two IV's each with two levels and 1 DV with two levels. The first IV was type of associated word which had two levels; noun and onomatopoeia. A within-subjects design was utilised so that every participant was exposed to both sets of words. The second IV was modality which also had two levels; audio or visual. A between-subjects design was implemented with each participant being randomly assigned to one of the two levels using counterbalancing with an equal number of participants in each condition. The DV of the study was number of words recalled using a recognition task. The DV also contained two levels, one level was the number of words recalled which were paired with onomatopoeia and the second level was the number of words recalled that were paired with nouns. The aim of the study was to investigate whether onomatopoeia words were processed differently to nouns in each modality condition.

Apparatus/Materials

Word lists were created for use in this study as a method of presenting the stimuli to participants. The first word list (Appendix 3) was created using online resources created by Paivio, Yuille & Madigan (1968) which contained 925 nouns which could be chosen based on a fixed number of criteria such as number of syllables, number of letters, imagery rating, concreteness, meaningfulness and Krucera-Francis word frequency. A total of 10 words were selected from this database with a table of averages being created based on the chosen criteria (See Table 1).

Table 1: Output from Noun Generator

	Mean	Standard Deviation	Minimum	Maximum
Krucera-Francis	65.00	24.15	50	100
Imagery rating	5.85	0.93	4.27	6.70
Concreteness rating	5.81	1.58	2.25	6.96
Meaningfulness	6.66	0.84	5.08	7.88
Syllables	1.40	0.69	1.00	3.00
Letters	4.70	0.82	4.00	6.00

The second word list contained 10 onomatopoeia words (Appendix 3) which were collected from an online database (Examples of Onomatopoeia, 2011). The words were chosen by the experimenter based on word length and familiarity so that they could be matched with the nouns chosen as part of the second word list. A third word list (Appendix 3) was produced using an online random word generator consisting of 20 words which were paired with either onomatopoeia or a noun. A randomiser was also used online to determine the word presentation order to reduce any patterns being created.

A Dictaphone was used to record the words so that they could be presented using an audio method. Each clip was imported into a computer program Audacity where they were edited to create a dichotic listening task.

Procedure

The first part of conducting the study was to gain ethical approval from the dissertation tutor to ensure that ethical guidelines were adhered to which are set out by both the University and the British Psychological Society. A preliminary ethical approval form (Appendix 1) was completed and approved which detailed the proposed study. After ethical approval was gained, participants were sought using an opportunity sampling method. Before the study could be conducted a consent form (Appendix 2a) which outlined the study and included contact details as well as information about withdrawing from the study had to be completed by each participant. Participants were then randomly assigned to one of four condition's; written stimulus with the target word on the right hand side, written stimulus with the target word on the left hand side, audio condition with the target word presented to the right ear or audio condition with the target word presented to the left ear with the onomatopoeia and nouns being presented on the same side for each condition. This meant that every participant had both onomatopoeia and nouns presented to them with half having them written and half being presented through audio. The study was conducted using PowerPoint as the method of presentation. Each PowerPoint presentation had a set of standardised instructions which differed between the audio and written conditions (Appendix 5).

The written condition slides contained twenty word pairs in a randomised order which were shown for five seconds each with ten word pairs containing onomatopoeia and a random word (Appendix 6) and ten word pairs containing a noun and a random word (Appendix 7). Between each word pair slide was a blank slide which the participants had to click on as a method of maximising participants attention to the experimental task. Each word pairing was separated by a black line with a dot running through the middle which was used as a control. This control was employed to minimise the chances of the participants only attending to one word on the screen as the target word for recall was on the same side of the screen for the whole slide presentation. This was counterbalanced with 8 participants having the target word on the left hand side and 8 having the target word on the right hand side. Once the slide presentation was completed they were asked to turn over a sheet which contained a list of forty words (Appendix 8) which contained the twenty random paired words and twenty foil words.

The audio condition slides contained twenty slides of audio clips which had been edited using a computer program called Audacity, each slide lasted three seconds. Each slide shown contained an image of a speaker which allowed for the audio track to be imported into the PowerPoint. The audio tracks were spoken word recordings of a single word with two word tracks being fused together and one being played through the right audio channel and the second being played through the left audio channel when wearing headphones. The same word pairing were used for both the audio and written conditions. For the audio condition the participants were not required to click on blank slides and each slide continued onto the next one. After all twenty audio clips had been played participants were asked to select from the list of forty words how many they recalled.

After participation was complete participants were given a debrief form (Appendix 9) with it being reinforced that they were able to ask any questions or withdraw their participation at any point by email and quoting their participant number. Participants were also thanked for volunteering to complete this study.

EEG Case Study: Comparison of brain activity during the processing of onomatopoeia and nouns

Participants

Participants were two students from the University of Gloucestershire (1 Male, 1 Female, Mean age -21.5 years, SD - .71 years). Participants had already completed the first part of the study and were selected due to them volunteering participation on the original consent from. They were approached as to whether they would still wish to further take part in this study.

Design

The EEG data were collected using the university EEG facilities which enabled the experimental task to be completed while gathering data to indicate which regions of the brain were most active. This allowed for the investigation of which brain regions were involved in the processing of onomatopoeia and nouns and whether these differ.

A change in methodology was implemented with no random word pairing used, this was due to the aim of the study being to investigate the processing differences between onomatopoeia and nouns.

Apparatus/Materials

The EEG apparatus used a 128-channel geodesic net (EGI^{TM}) to record the brain activity during the task. The data were amplified, filtered, sampled, digitised, packaged and sent to Macintosh computer running *Netstation* software which allowed artifact and eye movement detection and removal, averaging, average re-referencing and baseline correction of the EEG data. Further source localisation was performed using *Geosource* software to identify peak activity in terms of Brodmann areas 1.1sec after stimulus presentation. New word lists were created using the same resources as in the behavioural study (Appendix 4).

Table 2: Output from Noun Generator for EEG Study

	Mean	Standard Deviation	Minimum	Maximum
Krucera-Francis	70.00	25.82	50	100
Imagery rating	5.08	0.65	4.10	5.90
Concreteness rating	4.46	1.75	2.13	6.99
Meaningfulness	6.47	0.83	5.28	7.88
Syllables	1.70	0.48	1.00	2.00
Letters	5.60	0.52	5.00	6.00

Procedure

The EEG study was conducted as a follow up on the first part of the study; participants sought for the EEG had already completed the recall study some weeks earlier. As part of the first study informed consent was gained while also asking if they would be prepared to take part in a further section of the study which involved collecting data using an EEG machine. The participants chosen had agreed to this which was the basis of their participations. Further consent was gained (Appendix 2b) which detailed the procedure of using an EEG machine and verbal instructions were also given with the chance to ask any pending questions they may have had. An EEG net was applied to the participant by a qualified person and the procedure was supervised throughout the whole experiment. Each participant used the same materials which involved a PowerPoint presentation which flashed onomatopoeia and nouns (Appendix 4) in a randomised order with participants being instructed to remember as many as possible for recall afterwards. Once all stimuli had been presented the participants had to indicate on the keyboard whether the word being shown had been presented before, they were asked to press left if they did recognise the word and right if they did not had. The slideshow contained 10 onomatopoeia words and 10 nouns, at the recall stage twenty foil words were added also.

Participants were then fully debriefed and given the opportunity to ask any questions regarding the aim of the study or any other queries, they were then thanked for their time and participation.

Results

The collected data was interval level based on this the most appropriate method of analysis was a mixed effects ANOVA due to the two IVs with one being between-subjects (modality) and one being within-subjects (type of associated word). Before this can be conducted the normality of the data has to be checked. Assumptions of normality need to be tested for each variable being investigated with a skewness and kurtosis value being generated (Table 3). Each skewness and kurtosis value is divided by its standard error; if values of +/- 2.58 for skewness and +/- 2 for kurtosis are attained then normality is assumed. Histograms have also been produced to demonstrate normality (Appendix 10). Skewness and kurtosis assumptions were satisfied for all conditions.

Table 3: Skewness and Kurtosis Values for all conditions

	Skewness				Kurtosis			
	Statistic	S/E	Value	Assumption Satisfied Y/N	Statistic	S/E	Value	Assumption Satisfied Y/N
Written Modality - Onomatopoeia	.05	.56	.09	Y	-.42	1.09	-.39	Y
Written Modality – Nouns	-.11	.56	-.19	Y	1.43	1.09	-1.31	Y
Auditory Modality – Onomatopoeia	-.46	.58	-.79	Y	-.55	1.12	-.49	Y
Auditory Modality – Nouns	-.70	.58	-1.21	Y	-.06	1.12	-.05	Y

Leverne's test of homogeneity of variance was shown to be non-significant which indicates that there was sphericity across conditions. This allows for the investigation of participants scores across conditions (Field, 2005). To further test for outliers in the data boxplot graphs (Appendix 11) were produced with it being shown that 3 outliers are found in the data for the recall of onomatopoeia words which were still included in the analysis of the data.

A mixed factorial design analysis of variance (ANOVA) was conducted (Appendix 11), to determine whether there was a significant difference between modality and type of associated word on recall. Modality had two levels (audio & written) which was the first IV while type of associated word had two levels (onomatopoeia and nouns) was the second IV. The number of correctly identified words was the DV.

There was a non-significant main effect of associated word, $F1,29 = .25$, $p>.05$, ($\eta_p^2 = .01$, observed power = .08)

There was a non-significant main effect of modality, F1,29 = 2.07, p>.05, (η_p^2 = .07, observed power = .29)

There was a non-significant interaction between associated word and modality, F1,29 = .02, p>.05 (η_p^2 = .00, observed power = .05)

No post hoc tests were conducted. Results are further discussed with adaptions to the study being suggested should this be replicated.

EEG

The data collected was segmented to allow for the areas of greater activity to be investigated after the stimuli presentation and at time of recall. It was deemed appropriate to use data collected 1.1 seconds after the stimuli were first presented and also when participants were asked to indicate whether the word was recognised. The finding of initial interest is the Brodmann Area showing maximum activation at these times for each condition. The peak Brodmann areas are shown in Tables 4 and 5 and Figures 1 to 8 for each participant.

Table 4: EEG data for Maximum activity - Participant One

Condition	Presentation Time	Brodmann Area	Gryus	Lobe	Hemisphere
Onomatopoeia 1st Presentation	1.1 Seconds	40	Inferior Parietal	Parietal	Right
Onomatopoeia Recall	1.1 Seconds	11	Medial Frontal	Frontal	Midbrain
Nouns 1st Presentation	1.1 Seconds	20	Inferior Temporal	Temporal	Left
Nouns Recall	1.1 Seconds	38	Superior Temporal	Temporal	Left

Table 5: EEG Data for Maximum acitivity - Participant Two

Condition	Presentation Time	Brodmann Area	Gryus	Lobe	Hemisphere
Onomatopoeia 1st Presentation	1.1 Seconds	7	Superior Parietal	Parietal	Left
Onomatopoeia Recall	1.1 Seconds	22	Superior Temporal	Temporal	Right
Nouns 1st Presentation	1.1 Seconds	10	Middle Frontal	Frontal	Left
Nouns Recall	1.1 Seconds	11	Orbital	Frontal	Right

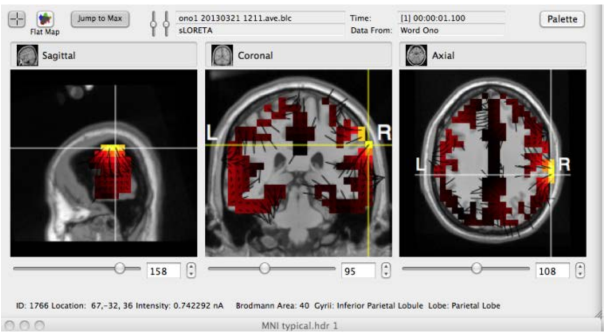

Figure 1: Participant One: EEG activation 1.1 Seconds after Onomatopoeia presented – Encoding

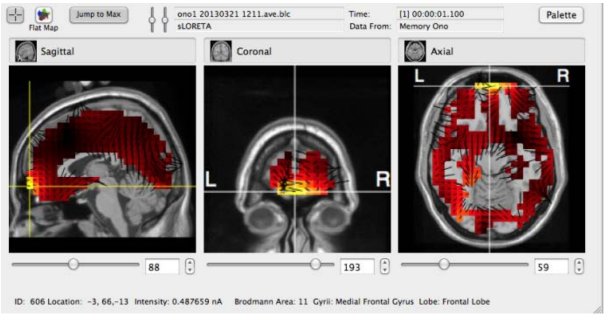

Figure 2: Participant One: EEG activation 1.1 Seconds after recall of Onomatopoeia - Retrieval

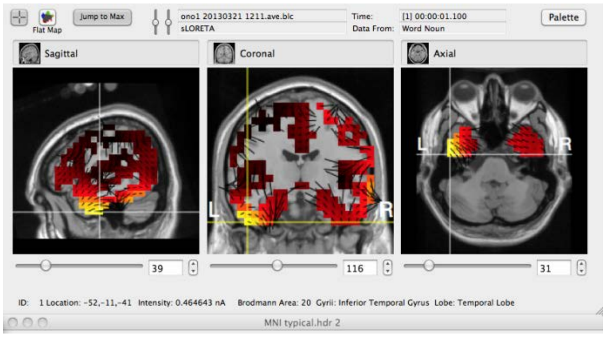

Figure 3: Participant One: EEG activation 1.1 Seconds after Nouns presented – Encoding

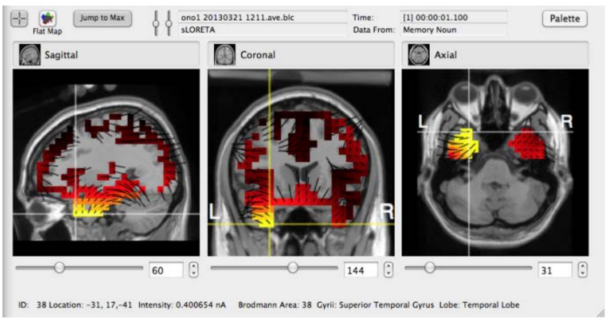

Figure 4: Participant One: EEG activation 1.1 Seconds after recall of Nouns - Retrieval

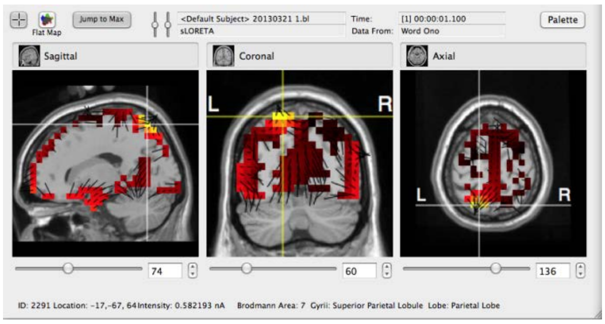

Figure 5: Participant Two: EEG activation 1.1 Seconds after Onomatopoeia presented - Encoding

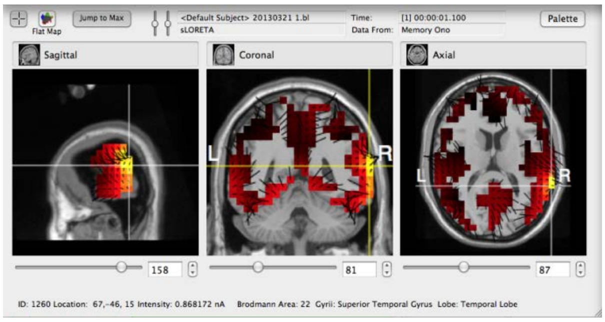

Figure 6: Participant Two: EEG activation 1.1 seconds after recall of Onomatopoeia – Retrieval

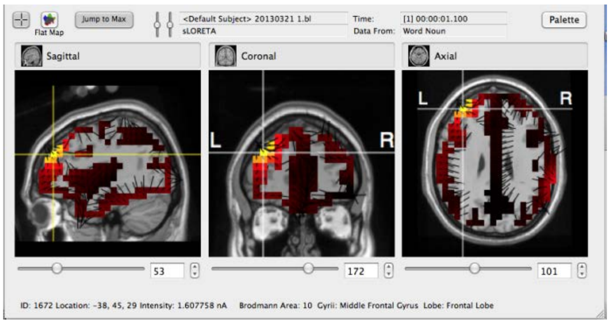

Figure 7: Participant Two: EEG activation 1.1 seconds after Nouns presented – Encoding

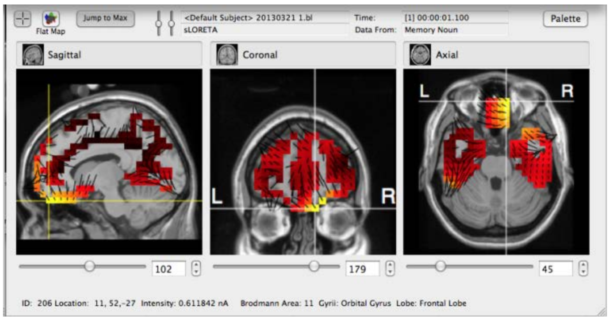

Figure 8: Participant Two: EEG activation 1.1 seconds after recall of Nouns - Retrieval

The spread of activation can also be interpreted by viewing the EEG output, it is advised to do so however with caution due to the use of only two participants in this case study. For both participants the spread of activation is invariably greater when encoding and recalling the onomatopoeia particularly from the axial view of the image. This greater spread in activation leads to the theorising of the more extensive brain regions that are engaged when processing onomatopoeia (Hashimoto, Usui, Taira, Nose, Haji, & Kojima, 2006). Further research would need to be developed to fully investigate this difference.

Discussion

The aim of the current study was to investigate the differences between the processing of onomatopoeia and other words (nouns). The experiment was conducted in two parts in which different data were collected to investigate these effects. The results from the main of the study were complimented by additional data in the second part of the study which was collected using an EEG machine which produced data on the brain regions most active when the stimuli are presented and recalled.

The results of the main analysis were shown to be non-significant; this states that modality and type of associated word had no-significant effect on a recognition task. The interaction between modality and type of associated word was also non-significant with no post hoc tests being conducted. Based on these findings hypothesis 1 can therefore be rejected. Prospective power was calculated prior to the experiment being conducted which stated that 64 participants would be required for each condition using a medium effect size in order to identify a significant difference should one be present between the variables (Cohen, 1992). SPSS allows for the calculation of observed power for each variable in the experiment. For each variable low observed power was discovered so it would not be sufficient to suggest that if more participants were recruited a significant effect would have been found. A suggestion for future research is for possible methodological changes which could results in an increase in observed power to meet the desired level of .80 (Coolican, 2004). SPSS output was used to calculate the mean score for each modality condition with it being indicated that participants scored higher in the written condition than they did in the audio condition but it was found to be a non-significant difference.

The main experiment was conducted using a recognition task with the effects of modality and type of associated word being investigated. Modality was a between-subjects condition with participants being assigned to either an auditory or visual group which defined how the stimuli would be presented. Type of associated word was a further variable which was conducted using a within-subjects design with each participant experiencing both onomatopoeia and nouns. Research suggests that the use of a dichotic listening task can induce cognitive load (Dittrich & Stahl, 2012) due to the person inability to actively attend to two stimuli being presented at the same time. Broadbent, (1957) model offers support for the theory of reduced recall through an auditory modality with Underwood, (1973) offering further support whereby dichotic listening tasks limit processing capacity with the ability to only actively attend to one channel with the other channel receiving limited processing capacity. This is akin to the theory of attenuation relating to the allocation of attention (Treisman, 1964). Literature has also presented findings for a right ear advantage in dichotic listening tasks (Thomsen, Rimol, Ersland, & Hugdahl, 2004; Hugdahl, Westerhausen, Alho, Medvedev, & Hamalainen, 2008), this was accounted for in the experiment with the presentation of the critical word being counterbalanced so it would either be presented to the right ear/visual field or the left ear/visual field depending upon the condition they were allocated to.

A decision was made to investigate the recall of onomatopoeia and nouns using them as paired words rather than direct recall. This method was adopted for the main experiment, whereas in the EEG component direct recall of the words was investigated. This difference in methodology was chosen as the data collected through the EEG enabled for the brain regions most active for the onomatopoeia and nouns rather than the processing of the paired ‘random’ word. EEG data allows for the comparisons of brain regions at different times to the millisecond, which allowed for comparisons at the encoding and retrieval of the words.

As stated no main effects of the experiment were found, little research has been conducted directly investigating these effects. The main experiment was devised as a method to investigate the effects of modality and associated word on recall, literature stated that extensive regions were activated in the processing of onomatopoeia (Hashimoto, Usui, Taira, Nose, Haji, & Kojima, 2006) which led this to be inferred that it may be due to cognitive load which could limit performance on a recall task (Dittrich & Stahl, 2012) and ultimately result in poorer recall for onomatopoeia words.

It is suggested that further research should be conducted to investigate these effects but alterations should be made to the methodology. A main change which could be suggested would be to test free recall of words rather than paired learning. Paired-learning was utilised in this study due to its suitability to the study as each word presented will be processed (Reber, 1985) which allowed for the effect of the type of associate word to be investigated. This effect was shown to be non-significant in the main experiment and adaptations were made for the procedure used in the EEG study. The direct processing of the onomatopoeia and nouns would be tested rather than as an associated word, Schimdt et al, (2002) applied a paired-learning task with modality also being manipulated and found that using a PET scan that extensive regions were activated regardless of modality. Due to possible interference from the headphone on the EEG data which is highly sensitive to background ‘noise’ (Banich & Compton, 2011) the audio condition for modality was not considered so only the written/visual condition was used.

Due to time constraints only two participants were collected for data using the EEG but had this not been an issue more participants would have been sought. This would have provided more evidence about the brain regions engaged when encoding and recalling onomatopoeia would and how this differs to other word types such as nouns, Literature surrounding this area was sparse barring one study conducted using an fMRI machine (Hashimoto, Usui, Taira, Nose, Haji, & Kojima, 2006), the results from this study were used as support for the creation and testing of the second hypothesis as it is a very under researched area in neuropsychology. For a methodological advancement on the testing of the second hypothesis an fMRI machine would have been used but it was deemed that the EEG machine could gain enough data regarding the localisation of the process to infer conclusions. A number of other variables may also need to be considered for further studying which could include level of education, age and occupation. These factors could impact upon the ways in which these words are processed on a neurological level and could produce more precise information on the subject.

Hypothesis 2 is untestable using statistical analysis but is supported using data collected using an EEG machine. It was found that onomatopoeia did activate more extensive regions than the nouns with the spread of activation being particularly greater when recalling onomatopoeia (See figures 1-8). Based on a literature review it was hypothesised that onomatopoeia would activated Brodmann area's 17,41 and 42 based upon literature (Morosan, et al, 2001; Tsunada, et al, 2011). Results indicated that for participant one at the presentation of onomatopoeia the most active region was BA 40 while at recall for participant two it was BA 22. These regions surround the Brodmann areas that were hypothesised to be active. Results from the EEG are averaged over a period of time which allows for data to be collected based on a number of trials. Using computer software called geosource allows for the EEG output to be viewed at different times, it was deemed that the results for this study would be taken 1.1 seconds after the stimuli were presented and recalled. Had this time been changed the regions of the brain most active may have in fact changed. A suggestion for future research would be to take readings at different times (e.g. 50m/s, 80 m/s etc.) after the stimuli have been presented to gain more of an insight into the regions activated.

Individual differences also need to be considered when interpreting the EEG data as neither participant produced the same Brodmann area as being most active at each stage of the research. Participant ones results after the initial presentation of onomatopoeia led to the greatest activation of BA 40, which is considered to be part of the phonological loop (Purves, et al., 2008). This region of the brain is considered to be an important element in the evolution and development of vocal language in humans (Aboitiz, Aboitiz, & Garcia, 2010). This could indicate that when the onomatopoeia were presented they were processed as a sound rather than a word which relates to the theory of phonics and phonology (Vachek, 1933). Participant two however had the greatest activation in BA 7 which is located in the superior parietal lobe (Bowyer, et al., 2009), this region of the brain is typically associated with visuospatial memory tasks (Knauff, Mulack, Kassubek, Salih, & Greenlee, 2002) while also being involved in the processing of mental and visual imagery (Pelgrims, Andres, & Olivier, 2009). The links found between BA 7 and imagery networks of the brain lead to some inference that for participant two when initially processing the onomatopoeia there may some form of 'picture' created of the onomatopoeia presented.

With regards to the processing and recall of nouns for participant two the main activated regions were BA 10 and BA 11 respectively whereas for participant one BA 20 and BA 38 were activated. BA 20 and BA 38 are considered to be regions associated with the Wernicke's region of the brain for the understanding of written and spoken language (Banich & Compton, 2011). The dominant hemisphere was also the left hemisphere which is considered to be the hemisphere typically associated with language (Purves, et al., 2008). BA 10 and 11 are located in the frontal lobe with BA 10 being associated with activation during retrieval tasks (Ranganath, Johnson, & D'Esposito, 2000) this was the main activated area 1.1 seconds after the nouns were presented, this may have been activated relating to retrieval as nouns are commonplace in the English language and so were activated through memory. While BA 11 is located in the orbitofrontal cortex and research has implicated this region in decision making with particular focus on high v low risk (Cohen, Heller, & Ranganath, 2005) which could be explained through the recognition task where participants had to indicate on the keyboard whether the word had been shown previously. An intensity value is also created for each result which could be used as another indicator as to the level of to which regions of the brain were most active across the participants results. For the initial presentation of onomatopoeia BA 40 had a higher level of intensity (0.74 nA) than BA 7 (0.58 nA), at recall BA 22 had a higher level of intensity (0.87 nA) than BA 11 (0.49 nA). For the nouns initial presentation the intensity value for BA 10 (1.60 nA) was higher than for BA 20 (0.46 nA) whereas at recall of the nouns BA 11 (0.61 nA) had a higher intensity than BA 38 (0.40 nA). This information could be used to suggest the region most active while incorporating both participants scores.

Further research would need to be conducted as an attempt to homogenise the neural activity found in the processing of these words. Although the regions found to have the highest level of activation differ to those hypothesised there is evidence to support these findings and offer explanation as to why this was found. A particular area of interest would be the activation of BA 7 and BA 40 in the original presentation of the onomatopoeia as these indicate that the onomatopoeia is not necessarily processed as a word but in fact either a sound or an image is created. These results would appear to indicate that at a neurological level onomatopoeia and nouns are processed using different regions of the brain with the regions used for the processing of nouns appearing to adhere to the convention of language regions whereas the onomatopoeia does not. With little research being located prior to this investigation the findings from this current study could become the basis for future research into this area.

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