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BRAINS RESPONSE TO SYMBOLS IN TYPICALLY DEVELOPING CHILDREN

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ABSTRACT

Purpose: Individuals who have communicative disorders rely on Augmentative and alternative communication (AAC) to interact with others. Many aided AAC devices use symbol sets as a way to express the English language. The iconic nature of symbols in opposition to the arbitrary nature of words has sparked interest among scientists. This study is designed to measure brainwaves to see if AAC symbols elicit the same response as spoken words.

Methods: Event Related Potentials (ERPs) were recorded and reported for 12 school-aged children. The N400, an index of semantic word processing, and N300, an index of semantic picture processing, were examined when participants were presented with a symbol and spoken word simultaneously.

Results: An increasing N400 effect was found with greatest disparity between congruent and incongruent trials in the 450ms-550ms epoch in the left parietal lobe.

Conclusions: The presence of an N400 indicates that the brain responds to symbols as it does spoken words. The later effect signifies that semantic processing is developmental.

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Chapter 1

Introduction

Over 4 Million Americans have severe communication disorders that prevent them from using natural speech (Beukelman & Mirenda, 2013). Augmentative and alternative communication (AAC) provides a means of communication for these individuals in which they can effectively and efficiently express their wants and needs, transfer information, form social relationships, and use social etiquette. AAC is comprised of two subgroups, unaided and aided. Unaided AAC methods are defined by gestures, sign languages, and some vocalizations. Aided AAC methods use an external aid, typically comprised of symbols, to communicate. A common symbol set used in aided AAC is the Picture Communication Symbols (PCS) system. This system consists of over 7,000 line drawings used to represent words.

Research conducted by Mizucko and Reichle (1989) determined that PCS and Picsyms were the most transparent symbol sets used for AAC devices. There were 20 intellectually disabled adults who participated in their study. When presented with three different symbol sets, they were instructed to point to the symbol that most resembled the word that was spoken to them. The results of Mizucko and Reichle's study were enhanced with a study conducted by Mirenda and Locke (1989) that distinguished a hierarchy of symbol usage. They studied 40 intellectually handicapped individuals ranging in age from 3 to 20 years old. The participants were presented with nine different symbols: color photographs, black and white photographs, colored line drawings, PCS, Picsyms, Blissymbols, and printed words. The result of the study showed that the photographs were the most transparent. If segmented to analyze the results of the symbols used in AAC devices, PCS were found to be the most transparent and easiest to learn in comparison to the other symbol sets. For these reasons, the symbols used in this study were pulled from the PCS inventory.

Methods of Communication

Individuals with and without communication disorders use symbols to communicate every day. The importance of symbols for communication has prompted new research in the field of AAC. One goal of the current research is to improve AAC symbols so that individuals are offered a form of communication comparable to spoken language. The signal involved in speech is auditory, temporal, dynamic and arbitrary. These characteristics indicate that words are derived from sounds spoken in a specific order to form an agreed upon meaning and "disappear" after spoken. The signal involved in AAC (symbols) is visual, spatial, static and often iconic. By definition, a symbol is "something that stands for or represents something else" (Beukelman & Mirenda, 2013). Symbols can either be transparent or opaque. Transparent symbols, such as an image of a dog, are meaningful even in the absence of a referent. Opaque symbols, such as the word "dog", have no relationship to the referent and are considered arbitrary.

Research has shown that developmental age contributes the most to children's abilities to understand images. Callaghan (1999) studied a group of 48 children's ability to draw and use symbols in a communicative setting. Simple drawings consisting of circles and lines were used in his study. The children were asked to use the drawn symbols to participate in a game. Callaghan found that the children who were 3 and 4 years old were able to better create and use symbols in a communicative setting. The 2 year olds were unable to make the connection between the symbols and the game. This research implies that individual's pictorial competence develops through childhood.

There is much debate among the scientific community as to the effectiveness of symbols used for communication. Symbol sets have proven to be effective for some individuals, but others struggle to use them to communicate. It is possible that more iconic or transparent symbols may not support the symbolic function served by arbitrary words.

Brain Imaging and Language

With the use of brain imaging we are able to compare and determine how the brain processes both words and symbols. A common imaging technique is scalp recorded Event Related Potentials (Barrett & Rugg, 1990). ERPs are an integral part of studying language processing and provide information about how the brain functions cognitively (Barrett & Rugg, 1990; Benau, Morris & Couperus, 2011). ERPs are extracted from brain activity that is time-locked to specific events, such as stimuli onset or motor response. This information is averaged among the electrodes to distinguish between the signal and extra noise (Federmeier & Laszlo, 2009). The average reflects the voltage fluctuations among processing activities occurring in different regions of the brain (Coch, Maron, Wolf & Holcomb, 2002). The different characteristics of the ERP can provide information about how the brain processes input (Benau et al., 2011).

The N400

The N400 component of ERP has been connected with the semantic processing of words in language (Barrett & Rugg, 1990). The N400 is a negative going peak 400ms after stimulus onset. Kutas and Hillyard (1980) first discovered the N400 component in a study designed to examine how the brain responded to semantically anomalous words at the end of a sentence. Seventeen young adults ranging in age from 19 to 35 were presented with sentences that ended with a congruent or incongruent word. The incongruent sentences were structured as follows, "I take coffee with cream and engine". The study found that the N400 component exists throughout the central and parietal regions of the brain if the anomalous word affected the meaning of the sentence.

A study completed by Besson and Macar (1987) examined the N400 in response to words, images, and music in 14 young adults to determine what stimuli elicit a response to incongruity. The study was comprised of four stimuli types: sentences, geometric figures, musical notes, and common songs. Twenty-five percent of the trials ended with an incongruent word, geometric figure, or musical note. Participants were asked to complete a recognition questionnaire during the breaks of the experiment. Besson and Macar (1987) found that the N400 was only present in the incongruent sentence trials. The results of this study confirm that the N400 is only evoked when there is semantic incongruity. Further more a study done by Coch et al., (2002) concluded that the N400 effect becomes more prominent as the word becomes more difficult to integrate into the sentence.

In addition to studying what elicits a N400 component, researchers have also begun to learn how the N400 evolves from childhood to adulthood. Friedrich and Friederici (2004) conducted a study with 80 children at the age of 19-months. The study presented the children with a colored picture of a single object. After a short period of time, while the image was still visible, the children were presented with a verbal word. Freidrich and Friederici (2004) found an n400-like response up to 400ms later (N800) and longer lasting than an adult's response.

Beanu et al. (2011) conducted a study with 20 adults and 20 children to examine how the brain processed semantically incongruent sentences across age groups. Subjects were presented with congruent, moderately incongruent, or strongly incongruent words at the end of the 6 to 9 word sentence. The children ranging in age from 8-12 had a more significant N400 in comparison to the adults, suggesting that as age increases individual's response to semantically incongruent sentences decreases. Furthermore, Coch et al. (2002) designed a study to evaluate 10 and 11 year olds brain responses to words and images. The children were presented with a set of animal words, pseudowords, random letter strings, false fonts, real pictures, pseudopictures, parts of pictures, and flashes. When the children saw an animal word or picture of an animal they were asked to press the response box. The study found both the N400 and N300 component in these children.

The N300

The N300 component of ERP is elicited when a semantic incongruity among images is present (Barrett & Rugg, 1990). The study developed by Coch et al. (2002) established a dual negative going peak in the anterior position between 350 and 420ms. This dual peak is suspected to be the same as the frontally distributed N300 found in adult tasks. A study conducted by Hamm, Johnson, and Kirk (2002) presented 32 young adults with a written word and either a congruent or incongruent black and white line drawing. Through analysis of the images a N300 was found for images that were semantically incongruent on the categorical level not simply physically dissimilar. The earlier onset of the N300 compared to the N400 suggests that objects are categorized before their specific identity is understood. When images violate semantic process the effect is seen first in the frontal region of the brain and then moves toward a central-parietal distribution.

Research Aims

The current study was designed to show that symbols have semantic information just as words do. The iconic nature of PCS symbols may make them dissimilar from the arbitrary spoken word. Further investigation must be done to establish the level of communication that is effective for both AAC symbols and spoken words. For this study, I asked how the visual representation of language compares to the auditory component of language in school-aged children. I hypothesized that the school-aged children would elicit a N400 for incongruent trials later than typical adults. I also hypothesized that we might see a N300 component due to the use of symbols. I expected the N400 to be distributed over the central and left regions of the brain. The N300 was expected to be most apparent in the frontal region.

Chapter 2

Methods

Participants

Thirteen school-aged children were studied in this research, 6 female and 7 male. The children ranged in age from 8 to 16. One participant was excluded from data analysis. This participant had an excess of artifacts because the session was conducted during a thunderstorm. The noise of the storm and movement of the participant caused a spike in amplitudes. During raw data inspection, it was observed that all electrodes exceeded 50% error indicating that the amplitudes were too distorted to gather data. Therefore, 12 participants were included in the statistical analysis, 5 female and 7 male. All participants were typically developing and attending middle school or high school in the State College Area. Participants had normal or corrected to normal vision. All children were recruited through The Pennsylvania State University. Participants were compensated $20 for their time.

General Procedures

Participants completed one session that was approximately an hour long. Prior to committing their child's time parents were given information regarding the research experiment. Parents scheduled the session at the Human Electrophysiology Facility at The Pennsylvania State University. The experiment was conducted in complete compliance to the IRB protocol set forth by The Pennsylvania State University.

To begin the session, the parents were asked to read and sign a consent form for their child. The researcher then read the assent form to the participant for their verbal assent. The form contained information regarding the purpose of the study, the task and the benefits to participating. The parents were also asked to complete a demographic questionnaire about their child. The questionnaire asked questions regarding their child's strengths and whether or not they had a formal diagnosis.

All participants completed the Peabody Picture Vocabulary Test fourth edition (PPVT-4; Dunn & Dunn, 2007). This test was administered to ensure all participants had the vocabulary necessary for the experiment. **Table 1** includes the raw scores for each participant indicating their cognitive competency.

Participant ID	Age		PPVT Standard Score	Gender
S2_WM	15 years	8months	129	Male
S3_PL	12 years	1month	Not recorded	Female
S4_MRJ	12 years	9months	116	Male
S5_MCL	10 years	7months	135	Female
S6_SJ	9 years	10months	93	Female
S7_EE	8 years	8months	130	Female
S8_EG	11 years	11months	141	Male
S9_DP	10 years	5months	120	Male
S10_DI	12 years	10months	99	Female
S11_CP	14 years	7months	102	Female
S12_WC	16 years	11months	124	Male
S13_WB	14 years	1month	121	Male
S14_HX	8 years	8months	135	Male

Table 1: Participant Age, PPVT score and gender

Stimuli

A multistep process was conducted to create and validate the stimuli before the conduction of the study.

Word and Symbol Selection. A group of undergraduate and graduate lab assistants collaborated to compile a list of 120 words and their corresponding symbols. The words were selected from the first 60 words of the PPVT-IV form A and B and the first 327 words from the MacArthur-Bates Communicative Development Inventories (MCDI; Fenson et al., 1993). Words that fell into the following categories were automatically eliminated: action verbs, body parts, colors, shapes, emotions, and general category terms (i.e. furniture, animal, food). The symbols were selected after the word list was compiled. Picture Communication Symbols (Mayer-Johnson, 1992) were used in this study. The word and symbol pair was examined together to finalize the stimulus list. The group of students ranked the pairing of the symbol and word on a scale of one to three, one being an "awful" correlation and three a "great" correlation. Pairs ranking at a two or three were included in this study.

Stimuli Preparation. The 120 words were voice recorded through the *Apple* program, *Garage Band*, and converted to sound wave files. The files were then transferred to *Gold Wave* and edited to ensure there was no sound prior to the word. The symbols were saved as jpeg files at the size of 200 x 171 pixels.

The stimuli were separated into congruent and incongruent pairs via a Random Integer Analyzer. In a congruent pair the spoken word and the symbol matched. In an incongruent pair the spoken word and the symbol did not match. The incongruent stimuli were paired by contrasting categories, for example apple (a food) was paired with bunny (an animal). Appendix A includes the spoken words used and their symbol correspondent.

After pairing the stimuli a second Random Integer Analysis was administered. This analysis determined the order of the stimuli. The order was adjusted so that no more than two consecutive congruent or incongruent trials were together. The stimuli were then ready for the experiment and were programmed in *Eprime 2.0.8.22*.

Experimental Procedure

Participants were fitted with a dense array 128-electrode HydroCel Geodesic Sensor Net from Electrical Geodesics, Inc. (EGI). This net provided EEG recording during the experimental session. The sampling rate was 1000 Hz, amplified by Nat Amps 250 and low-pass filtered at 400 Hz. Impedances for all electrodes were below 50-kilo ohms, prior to the start of the study. The impedances were also calculated halfway through the experiment and corrected to be below 50-

kilo ohms. All electrodes were referenced to the Cz electrode at the time of acquisition, and re-referenced to the whole brain average during data processing and analysis.

After being fitted with the net, participants sat in a chair that was a comfortable distance away from the monitor. The room had a dim light and one speaker adjusted in volume so that participants could hear the words.

The study began with a block of practice trials. The participants were presented with a screen that read "press any button when you are ready to begin." After a button was pressed a fixation cross (+) appeared on the screen, varying in time from 500ms to 1500ms. The stimuli were then presented, a spoken word and a symbol simultaneously, for 2000ms. A response screen followed this. The participants had as much time as needed to respond to the stimuli. When participants responded they were reinforced with a set of smiley faces and sayings such as "good job" and "keep up the good work". **Figure 1** illustrates the order and time of the trials.

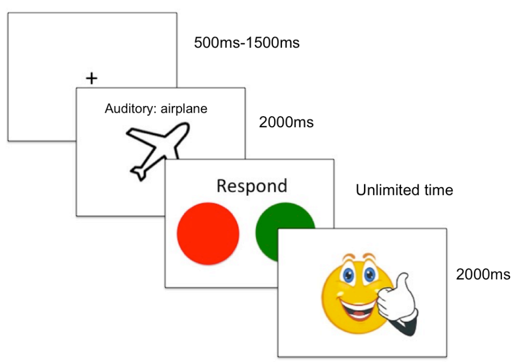

Figure 1: Stimulus trial

Participants were given a response box. They were instructed to press the button with a green sticker if the word and the image matched and the button with the red sticker if the word and the image did not match. Participants were asked to remain still during the experiment, but they could stretch on breaks.

After the practice block was complete the participants were asked if they had any questions. Once the experimenters were assured that the participant understood the process the experimental session began. The experiment was separated into 12 blocks containing 10 stimuli in each block. This provided the participants with time for a break if necessary. It took most participants about 15 minutes to complete the task.

Preprocessing

The data were preprocessed using *Net Station 4.3.1* from EGI and *BrainVision Analyzer 2.0*. During acquisition, trials were tagged to distinguish between congruent, incongruent, correct, and incorrect. In *Net Station* the incorrect trials were filtered out and disregarded for analysis. The filtered data sets were then transferred to *BrainVision Analyzer V.2.0.2 (BVA*). A high pass filter at .1Hz and a low pass filter at 80Hz were applied to the data to eliminate the excess noise.

The Gratton and Coles (1983) method was used to correct for vertical and horizontal ocular movements. The raw averages for each condition were subtracted from the corresponding single trial records. The EEG data were then considered as a dependent variable for the regression computation. The regression computation was used to derive the correction factors. These factors were computed separately for blinks and eye movements. Blinks were detected by locating all time points in the EOG record where the rate of change in electrical activity exceeded criterion. The raw data were then "corrected" with this information.

After eye movement correction, the data was referenced. A visual inspection was conducted to eliminate electrodes that had a percent error over 50. BVA recorded an error when there was amplitude over 200μV or under -200μV. The trials were re-referenced and averaged to the whole brain. At this stage of the processing, one participant was excluded from the analysis. Her data contained significant artifact from body movement that disrupted the brains signal. The remaining 12 participants' averaged data was segmented into congruent-correct and incongruent-correct epochs from 200ms before the stimuli and 1000ms after. Artifacts were tagged in each segment. A visual inspection eliminated trials that had amplitudes over 200µV or under -200µV in more than 10 electrodes between -100ms and 600ms. An average among each participant was created. The data sets where pooled into the areas of interest (a) Pz (b) Cz (c) frontal lobe (d) right and left parietal lobes. Appendix B includes all of the steps necessary to complete the pre-analysis process.

Data Analysis

The segments above were averaged for each participant creating two ERP segments (congruent and incongruent). The ERPs were then averaged across all participants to create a grand average. The mean amplitudes were calculated between 250ms-350ms, 350ms-450ms, and 450ms-550ms after the onset of the incongruent word. Averages were computed for the areas of interest: Pz, Cz, and the average of electrodes in the frontal, right parietal, and left parietal.

One-tailed paired t-tests were conducted to determine whether the average magnitude of the brainwave for the congruent trials differed from that of the incongruent trials. P-value was originally set at .05. The p value was adjusted by dividing it by 5 because t-tests were conducted for each of the five brain regions measured in each epoch (Cz, Pz, frontal, right parietal, left parietal) therefore indicating multiple comparisons. Thus, the final p-value used was .01 (.05/5).

Chapter 3

Results

A visual inspection of the grand average waveforms illustrated a difference between the congruent and incongruent stimuli. The average of the participant's data showed an increasingly negative peak with greatest disparity between incongruent and congruent trials between 450ms and 550ms. The effect was most prevalent in the left parietal lobe. The 250ms to 350ms epoch showed no effect, indicating that the stimuli did not elicit an N300 response.

Most participants had artifacts from movement throughout the experiment. We calculated the percentage of trials used by dividing the number of trials used in analysis over the number of trials correct. On average 47% of trials were used for congruent trials and 50% of trials were used for incongruent trials.

Statistical Analysis

The statistical analysis was done with a 1-tail paired t-test. Five brain regions were observed: Cz, Pz, frontal, right parietal and left parietal. Average amplitudes were recorded for congruent and incongruent trials at the desired epochs: 250ms-350ms, 350ms-450ms, and 450ms-550ms. **Table 2** shows the t-values and p-values among congruent and incongruent trials across the specified time epochs and brain regions.

		CZ	PZ	Frontal	R. Parietal	L. Parietal
250ms-350ms						
	T	-0.22	0.28	-0.74	-0.03	1.42
	P	0.4135	0.3907	0.2374	0.4887	0.0922
350ms-450ms						
	T	0.04	0.51	-0.66	-0.46	1.60
	P	0.4831	0.3083	0.2610	0.3257	0.0691
450ms-550ms						
	T	0.92	1.28	-0.94	1.02	2.78
	P	0.1887	0.1130	0.1834	0.1637	0.0089 *

* Indicates statistical significance

Table 2: T-Values and P-Values for time epochs and brain regions

No statistically significant differences were found for Cz, Pz, frontal, or right parietal in any of the epochs. **Figure 2** illustrates the average amplitude for the congruent and the incongruent trials, within each epoch, for the average of electrodes in the left parietal region. The average differences were not statistically significant at the 250-350 epoch (p = .09) nor at the 350-450 epoch (p = .06). At the 450-550 epoch, the average difference between congruent and incongruent trials was statistically significant, t(1,11) = 1.42, p = .009.

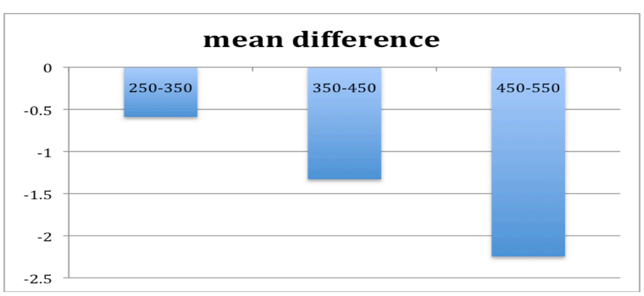

Figure 2: Mean difference between incongruent and congruent trials

Chapter 4

Discussion

This study was designed to gain insight on how the brain responds to iconic symbols used in AAC, in order to better adapt these symbols for communication. The current study used event related potentials to examine the response evoked by the brain when presented with spoken words and visual images simultaneously. The results concluded an increasing negative going peak with the greatest disparity between 450ms-550ms after stimuli onset in the left parietal region.

Through brain imaging scientists are able to learn how the brain processes language. The study of the N400 and the N300 provide vital information for the study of words and images. The leading research study conducted by Kutas and Hillyard (1980) discovered the N400 component in semantically anomalous words at the end of a sentence. Further research indicated that the N400 is only present when a word changes the meaning of a message (Besson and Macar, 1987).

The current research focused on a population of children ages 8 to 16. The later negative going peak observed in this study is consistent with the previous research done by Freidrich and Friederici (2004). The stimuli in this study were different from previous research because they were developed to use auditory and visual input simultaneously. Previous studies were designed to use either auditory or visual input. In some studies (Besson and Macar, 1987) both types of input were used, but the input was presented at different times throughout the experiment. In this study we found a N100 effect. This effect suggests that the participants were distinguishing between the auditory and visual input.

The location of the N400 effect in this study is similar to that of others. The most prominent area to elicit an N400 is the central and left parietal region. Some variations in that location have been recorded. Barrett & Rugg (1990) observed a frontal N300 and a more widespread N450 in their study. Coch et al., (2002) observed a N360 that was frontally located and a N460 in the left hemisphere, in their study of children. In this study, the effect was found in the average of the left parietal electrodes and was most pronounced at the 450-550ms latency. This has two implications. First, it would appear that as long as an auditory stimulus is present, the posterior-located and later effect is observed (ie, not the frontal N300 seen with all-picture stimuli). Second, the delay in amplitude suggests that the topography of the effect is not fully adult-like in early adolescence.

The results of this study indicate that symbols and spoken words elicit the same brain response and both carry function. In regards to AAC, these findings equip future researchers with the ability to make adjustments on AAC symbols for increased effectiveness and ultimately better communication. This study provides researchers with a good foundation for further investigation of the brains response to symbols. The population of interest regarding AAC is individuals with communicative disabilities, whereas this research studied children who were typically developing. The next step would be to conduct the study with individuals who have communication disabilities. Little is known about how this population's brain responds to language demands. The results of further research would enable symbols to be adapted to better fit the needs of individuals who need AAC to communicate on a daily basis.

In conclusion, while more research needs to be done, this study suggests that the brain responds to symbols the same way it does to spoken language. The results provide electroencepholographic (brain-based) support for the use of symbols as an effective form of communication.

Appendix A

Stimuli Used: Spoken Word (symbol)

1. Chicken
2. Airplane
3. Apple (bunny)
4. Knife (dress)
5. Pig
6. Ball
7. Truck (clock)
8. Scissors
9. Clock (mouse)
10. Popsicle
11. Motorcycle (elephant)
12. Bed
13. Fork
14. Cake (lamb)
15. Helicopter
16. Pretzel (mittens)
17. Horse
18. Book (cake)
19. Shoe
20. Drum
21. Firetruck (pretzel)
22. Monkey
23. Toothbrush (motorcycle)
24. Popcorn
25. Dress (apple)
26. Boat
27. Giraffe (train)
28. Cat (flag)
29. Frog
30. Squirrel (candle)
31. Bus
32. Butterfly
33. Zebra (castle)
34. Lion
35. Scarf (book)
36. Coat
37. Pumpkin (toothbrush)
38. Flag (bear)
39. Boots
40. Bug (cat)
41. Ice Cream
42. Barn
43. Mouse (knife)
44. Train (hat)
45. Dog
46. Hat (bug)
47. Bicycle
48. Bread
49. Elephant (fire truck)
50. Castle (giraffe)
51. Carrot
52. Lam (scarf)
53. Turtle
54. Pizza (zebra)
55. Mittens (squirrel)
56. Hammer
57. Bear (truck)
58. Cow
59. Bunny (pumpkin)
60. Candle (pizza)
61. Balloon
62. Bird
63. Turkey (present)
64. Grapes (socks)
65. Strawberry
66. Whistle (turkey)
67. Spoon
68. Caterpillar (spaghetti)
69. Cup
70. Bottle
71. Vest (bat)
72. Telephone
73. Tree (door)
74. Envelope
75. Couch (owl)
76. Belt
77. Doll
78. Lamp (butter)
79. Flower
80. Cookies
81. Socks (bowl)
82. French Fries
83. Zipper
84. Blocks (stroller)
85. Shirt
86. Butter (whistle)
87. Spaghetti (umbrella)
88. Kangaroo
89. Teddy Bear (caterpillar)
90. Pencil
91. Duck
92. Pear (couch)
93. Corn
94. Fire (money)
95. Umbrella (teddy bear)
96. Keys
97. Camera (sandwich)
98. Bat (pear)
99. Glasses
100. Crayons (grapes)
101. Crib
102. Ruler
103. Towel (lamp)
104. Bowl (tree)
105. Banana
106. Pants
107. Chair
108. Fish (vest)
109. Button (blocks)
110. Penguin
111. Cobweb (camera)
112. Door (towel)
113. Feather
114. Stroller (cobweb)
115. Money (fish)
116. Bee
117. Sandwich (button)
118. Bubbles
119. Present (crayons)
120. Owl (fire)

Appendix B

Data Collection: Net Amps 250, Net Station 4.3.1, and E-Prime 2.0.8.22
Data Analysis: Net Station, Brain Vision Analyzer 2.0,

<u>Net Station Steps</u>

1. Create Tools (Net Station > Tools > Waveform tools)
    a. Create .1 Hz High Pass Filter Tool
        i. Click “Create”
        ii. Select “First Order High Pass Filter”
        iii. Change filter settings to 0.1Hz
        iv. Close
    b. Create Congruent and in congruent filter
        i. Click “create”
        ii. Select “ segmentation”
        iii. Name segmentation
        iv. Create settings
            1. Cong +Correct
                a. Criteria set 1: Code is cong
                b. Between 1 and 2: select after and the 4th option
                c. Criteria set 2: Code is TRSP
                d. Between 2 and 3: Select coincident and 3rd option
                e. Criteria set 3: key code eval is 1
            2. Cong + incorrect
                a. Same as above
                b. Criteria set 3: eval is 0
            3. Inco +Correct
                a. Criteria set 1: Code is inco
                b. Between 1 and 2: select after and the 4th option
                c. Criteria set 2: Code is TRSP
                d. Between 2 and 3: Select coincident and 3rd option
                e. Criteria set 3: key code eval is 1
            4. Inco + incorrect
                a. Same as above
                b. Criteria set 3: eval is 0
    c. Create Export Data Tool
        i. Click “Create”
        ii. Select “Export File”
        iii. Rename to Export2BVA
        iv. Edit output options:
            1. Name: select -> Append
                a. Type in .raw
            2. Destination: same as source
2. Filter data

a. Open data from Brain Vision Analyzer
b. Tools > Waveform tools
c. Drag to file to input section
    i. Select high pass filter
    ii. Run
    iii. Produces at .fil
    iv. Copy file
d. Drag that file to input
    i. Select stim cor/incorr filter
    ii. Run
    iii. Edits file selected re name .fil stim
e. Drag that file to input
    i. Select Export2BVA
    ii. Run
    iii. Produces at .raw file
    iv. Rename to shortest possible name and only use one (.)

*****make sure the filename is short and does NOT contain spaces*****

If the filename does contain spaces, rename the files:

1. *Go to Start > Run > type 'cmd' > click 'ok'*
2. *Navigate to the folder where all of the files are using 'cd' (I find it easiest to copy and paste the directory structure from the window)*
3. *Dump all of the filenames into a .txt document*
    a. *At the command prompt, type 'dir /b > filename.txt'*
4. *Open the .txt document with Excel*
5. *Move the first column to the second column*
6. *The first column should say 'rename' in all rows*
7. *The second column should say the current filename (Note: if there are spaces in the filename, it must be surrounded by quotes , e.g. "filename 01")*
8. *The third column should say the new filename*
9. *Save this as .xls and as .prn (space delimited file)*
10. *Open the .prn file in notepad and save this file as a .bat file.*

<u>Brain Vision Analyzer</u>

In a data analysis folder create the following folders:

BVA
DATA
History
Export

1. Open Brain Vision Analyzer
2. Create a new workspace
    a. File > New
    b. Select a name for the workspace

    c. Save it in the same folder where the folders from step 1 are located
3. To move data into brain vision analyzer
    a. Move files to the data folder
    b. Restart BVA

History Template: Name of choice.ehtp

4. Open History Template: History Template > Open
5. Apply History File
    a. This will apply the process to the raw data
    b. History Template > Apply to History File(s)
    c. Select the correct History Template
    d. Starting Position = Root ("Raw Data")
    e. Select 'Primary History Files Only' and 'Select Individual History Files'
    f. Add any 'Available Files' to the 'Selected Files'
    g. OK
    h. You can also drag the history file to the start of the data

<u>Data Process!</u>

6. .1-80Hz Butterworth Zero Phase Filter
    a. Transformations > Data Filtering > IIR Filters
        i. Low Cutoff = .1
        ii. High Cutoff = 80
        iii. OK

7. Ocular Correction Vertical – Horizontal– Gratton and Coles Method
    a. Transformations > Ocular Correction
        i. Check the box for VEOG channel & HEOG channel
        ii. Channel Name = 126, 127, 120
        iii. Reference Channel = 8, 25, 43
        iv. Blink Detection = By Algorithm
        v. Disable the channels related to eye blinks and movement (120, 126, 127, 25, 43, 8)
        vi. Enable all other channels
        vii. OK

8. Complete raw data inspection
    a. Transformations >Artifact Rejection/Reduction>Raw Data Inspection
    b. Inspection Method
        i. Method =Automatic Inspection
        ii. Mode: check the box for 'Individual Channel Mode'
    c. Channels
        a. Enable All Except: VREF, 8,25,43,120,126,127
            i. The reference and channels used to detect eye blink and eye movement should not be used.
    d. Criteria
        i. Gradient (x)
            1. Uncheck the box for 'Check Gradient'

ii. Max-Min (x)
1. Uncheck the box for ‘Check maximal difference of values in intervals’
iii. Amplitude (x)
1. Check the box for ‘Check maximal and minimal amplitude’
2. Keep defaults (-200 to 200)
iv. Low Activity (x)
1. Check the box for ‘Check low activity in intervals
2. Keep defaults (.5
e. For next step disable all electrodes above 50%

9. Re-reference to the Average Reference
   a. Transformations > Channel Preprocessing > New Reference
      i. Select all ‘Available Channels’ as the ‘Selected Channels’
      ii. Remove the eye channels from the ‘Selected Channels’ column
      iii. Remove the electrodes above 50% from the ‘selected channels’
      iv. Check the box for ‘Include Implicit Reference into Calculation of the New Reference’
      v. ‘Next’
      vi. Select all ‘Available Channels’ as the ‘Selected Channels’
      vii. ‘Next’
      viii. Name of the New Reference Channel = Avg Ref
      ix. Check the box for ‘Reuse Old Reference Channel
         3. Name of Channel = Cz
      x. ‘Finish’

1. Segment each Tag separately
   a. Transformations > Segment Analysis Functions > Segmentation
   b. ‘Create new Segments based on a marker position
   c. ‘Do not store data, calculate data on demand’
   d. Next
   e. Add 1 marker
      a. Congruent+correct
      b. Incongruent+correct
   f. Next
   g. ‘Based on Time’
      i. -200 to 1000ms
      ii. Allow overlapped segments
      iii. Skip bad intervals

2. Artifact rejection
   a. Transformations > artifact rejection
   b. Semiautomatic segment selection
   c. ‘Channels’ > Enable all channels except eye (120,126, 127, 25, 43, 8)
   d. Disable all “bad” electrodes (those above 50%)
   e. Criteria
      i. Gradient: max allowed 50, mark as bad 200ms before and after
      ii. Max-Min: max allowed 200, interval length 200, mark as bad 200 before and after

iii. Amplitude: un check
iv. Low activity: lowest allowed .5, interval 100, mark as bad 200ms before and after
v. Intervals: un check

f. When doing artifact rejection: click through the trials and eliminate those 'marked as bad' between 0ms and 600ms

3. Baseline Correction
   a. Transformations > segment analysis functions > Baseline Correction
   b. Begin -200
   c. End 0
4. Transformations > Segment Analysis > Average
   a. Use full range
   b. Enable individual channel mode
   c. Create a data set for standard deviation
   d. Calculate SNR
5. Pooling
   a. Transformation > channel preprocessing > pooling
   b. # of pools: 5
      i. Cz: Verf
      ii. Pz: 62
      iii. Frontal: 1, 2, 3, 4, 5, 8, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 32, 33, 34, 116, 117, 118, 122, 123, 124
      iv. Right Parietal: 78, 79, 80, 85, 86, 87, 92, 93, 98, 103, 104, 105, 106, 110, 111, 112, REF, 57
      v. Left Parietal: 6, 7, ,13, 29, 30, 31, 35, 36, 37, 41, 42, 47, 52, 53, 54, 55, 60, 61, 62
   c. Add the name and select the electrodes to be in each pool

<u>Grand Average:</u>

1. Transformation > segment analysis functions > result evaluation > grand average
   a. Name of history files
      i. Average_inco
      ii. Select individual history files
      iii. Select all participants
      iv. Change output file name
2. Difference wave
   a. Transformations > comparison and statistics > Data comparison > difference
   b. Select files to compare

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