BEHAVIORAL AND ELECTROPHYSIOLOGICAL CORRELATES OF FACE PROCESSING: an ERP study

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ABSTRACT: Event-related potentials (ERPs) associated with visual face perception were recorded from 12 healthy volunteers. Subjects performed a visual target detection task where they were presented a variety of images, each for 250ms. They were instructed to make one response when they perceived a human face and a different response when they saw no face. Three categories of faces were presented: unmodified photographs of human faces, photographs that had been blurred, and photographs that contained an overlying layer of visual noise. Unmodified faces elicited a negative potential at 175 ms (N170), consistent with other studies. Blurring did not affect N170 amplitude, but resulted in a longer latency and more errors in target detection. Noisy faces yielded error rates comparable to blurred faces, but did not elicit N170. The absence of N170 could be caused by complexities involved in scalp recording, or could be indicative of multiple neural pathways by which face detection can be accomplished.

INTRODUCTION:

Human faces are among the most important objects we view. They provide some of the most salient features that distinguish person from person. Faces can convey states of fear and emotion extremely rapidly, and there is some reason to believe that because of this our brains possess 'wetware' specialized to process facial information. A variety of sources of evidence lend support to this hypothesis and are briefly reviewed below.

Among the earliest indications that we possess special neural mechanisms involved in processing visually observed faces was the discovery of individuals in whom face perception had been selectively impaired, while other cognitive abilities were spared. Prosopagnosia is now a well-documented pathological agnosia in which an insult, or more commonly, multiple insults to the brain cause a deficit in the capacity to overtly recognize familiar people. While prosopagnosiacs retain the ability to recognize familiar individuals via other modalities, and interestingly give increased electrodermal skin conductance responses to familiar faces, they are unable to recognize even pictures of themselves (Tranel, D., & Damasio, A. R., 1985). The condition is most commonly induced by bilateral damage to the occipitotemporal cortices, suggesting that these areas are involved in face processing (Farah, 1990). One important problem with this source of evidence, however, is that lesions in the brain brought about by events like stroke are rarely circumscribed, and often impair a variety of tissue without regard to anatomical boundaries or physiological specialization.

In a different approach, researchers conducting invasive intracranial recordings from the temporal cortex of macaque monkeys have discovered the presence of cells responding preferentially to faces (Gross, Roche-Miranda, & Bender, 1972, cited in Tong *et al.*, 2000). This finding has been replicated in human subjects who have undergone surgery for clinical reasons (Allison, *et al.*, 1994; Ojemann, Ojemann, & Lettich, 1992, cited in Tong *et al.*, 2000).

Numerous positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) studies involving normal subjects have also found increased activation of the ventral extrastriate cortex during tasks that involved viewing faces. (Kanwisher, McDermott, & Chun, 1997; Allison, *et al.*, 1994; Tong *et al.*, 2000; Haxby, *et al*. 1993, reported in Bentin, *et al.*, 1996). Activation is bilateral, but several imaging studies have indicated larger activation in the right hemisphere than the left.

Functional imaging studies of this area, now called the fusiform face area (FFA), (Kanwisher *et al.*, 1997) have provided excellent information about the anatomical source of face-related activity, but incomplete information about the temporal course of the activity. These functional

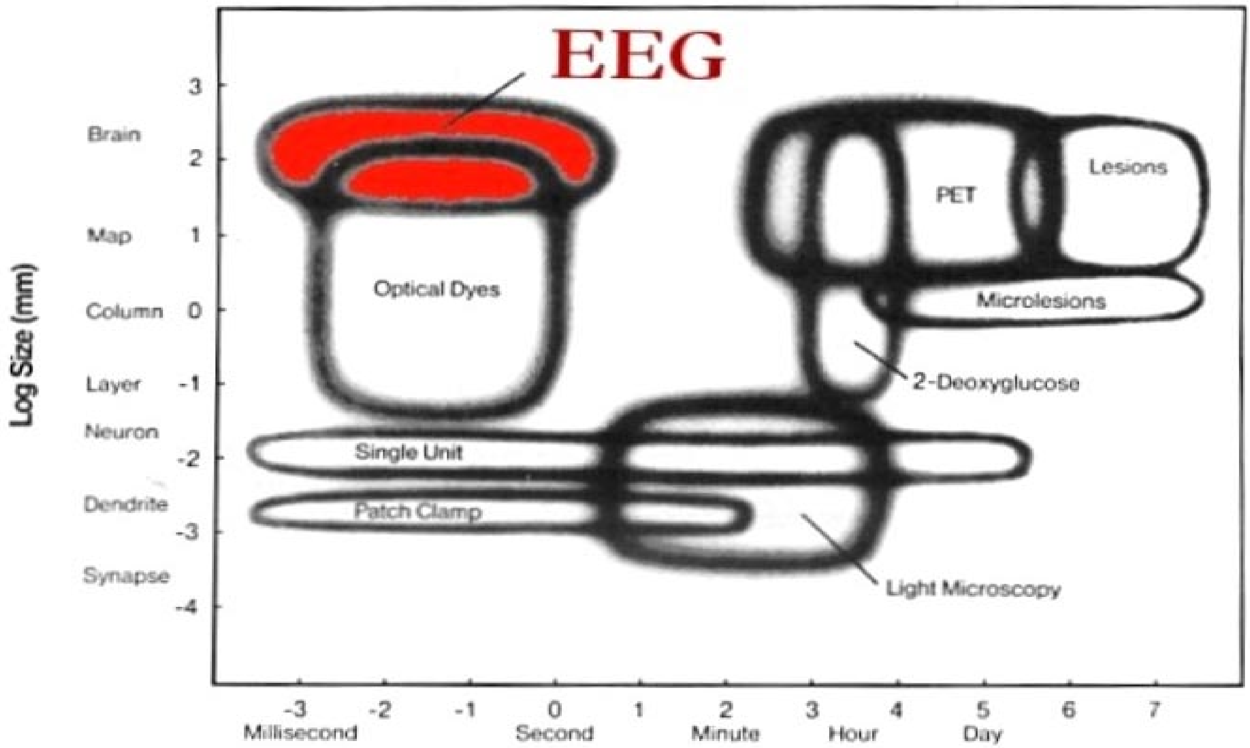


Figure 1. Schematic illustration of the spatial and temporal ranges of various experimental techniques. Note that EEG offers excellent temporal resolution, but poor spatial resolution. (from Churchland & Sejnowski, 1992)

neuroimaging devices often have temporal resolutions as high as 1Hz. In contrast, event-related potential (ERP) techniques often have temporal resolutions of 1000Hz, but provide incomplete information about the anatomical origins of the signal. Figure 1 provides a comparison of temporal and spatial resolutions for various experimental techniques.

ERP studies conducted with electrodes placed directly on the surface of the occipitotemporal cortex found discreet areas where faces evoked a negative component with a mean latency of 192 ms (Allison *et al*., 1994, Allison *et al*., 1999). This waveform component, deemed the N200, is not evoked by other complex stimuli such as hands, letterstrings, flowers, or cars. In these studies, waveform amplitudes for faces were larger when recorded from the right cortex than from the left.

Noninvasive extracranial ERPs have discovered similar activity at electrodes placed over the posterior temporal scalp. Bentin *et al*. (1996) reports that human faces evoked a negative potential at 172 ms (deemed N170), which was absent from ERPs elicited by other complex stimuli. N170 is not attenuated by repeated exposure to faces, and does not vary with regard to the subject's degree of familiarity with the face being presented. These attributes, along with the fact that N170 comes relatively early after stimulation, suggests, that it is reflective of an autonomous face detection mechanism. While the anatomical relationship between the source of the N200 and the N170 is not known, Bentin *et al*., provides a working hypothesis, a schematic illustration of which is presented in Figure 2. Because N170 activity can be recorded from scalp electrodes, there exists the opportunity to investigate it inexpensively in healthy subjects.

This study sought to study to accomplish two objectives: first, to further delineate the response properties of ERPs collected at posterior temporal scalp electrodes, and second, to investigate the relationship between N170 and the behavioral reports of healthy subjects. In contrast with all preceding studies, this study aimed to have participants en-

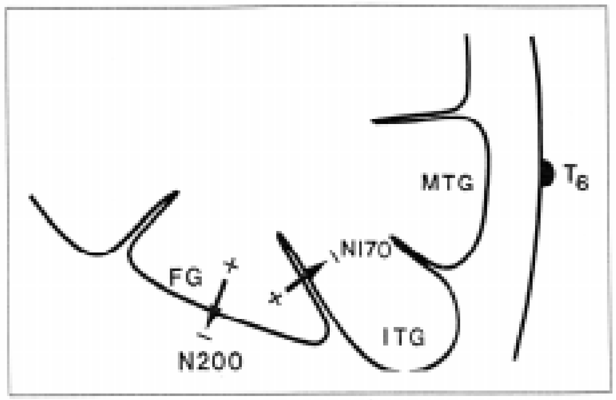


Figure 2. Schematic illustration of a working hypothesis for the origins of N170 and N200 potentials. Note that electrode T6, seen on the right, is closest to electrode P8 in the electrode array used for this study. Abbreviations: FG, fusiform gyrus; ITG, inferior temporal gyrus; MTG, middle temporal gyrus. (from Bentin et al., 1996)

gage in a detection task where human faces were the target stimulus. I hypothesized that electrophysiological activity would consistently correlate with the behavioral reports of subjects, such that when subjects reported seeing faces N170 activity would be present. I initially proposed to investigate these two areas using a plethora of stimulus types, but eventually simplified the study to consist of three separate experiments.

In previous ERP studies involving N170 activity, subjects were engaged in target detection tasks where non-face stimuli were designated as targets. Experiment 1 was designed to determine if N170 activity could be elicited when *faces* were designated as the target stimulus. I hypothesized that if the mechanisms that give rise to N170 activity are really cognitively impenetrable, face specific ERP activity would be recorded despite the fact that subjects were searching for faces. Experiments 2 and 3 were conducted for two reasons: to determine the effect of image manipulation on N170 activity, and to determine if N170 activity was present when subjects reported seeing faces in images that had been manipulated. The two experiments were identical in their design and implementation except that stimuli in Experiment 2 had high spatial frequency information removed via blurring, while stimuli in Experiment 3 possessed high spatial information added via addition of random visual noise. I predicted that for categories of stimuli where subjects reported observing faces, N170 activity would be recorded. In other words, the behavioral and electrophysiological data would correspond.

GENERAL METHODS:

Subjects:

Twelve volunteer subjects were recruited from the undergraduate community of Hampshire College, Amherst, MA. The mean age of participants was 23 years, and the range was 21 to 33 years. 83% of the participants were right hand dominant, as assessed by the Edinburgh Handedness Inventory. The twelve subjects each took part in the three experiments reported herein, and none participated in any other experiments. The total testing period for a given subject lasted approximately 90 minutes. The methods used in this study were approved by the Institutional Review Board (IRB) of Hampshire College, and informed consent was obtained from each subject.

Stimuli:

Stimuli were digitized photographs used in Allison, *et al.*, 1999c. The photographs were all the same size, resolution, and were all gray-scale images. Stimulus presentation was accomplished via computer monitor, and subjects were seated such that the images subtended 8.4x8.4degrees of visual angle. Each image was presented for 250 ms, and the interstimulus interval, filled by a white field, varied randomly between 1 and 2 s. For each experiment and each subject, stimulus order was randomized. Stimulus timing was controlled by the Superlab software package (Cedrus Corporation, San Pedro, CA). A QBasic program was written to generate Superlab scripts for each experiment (see Appendix 3)

Task:

The subjects were required to respond to each image. Because of the manner in which the experiments were conducted, it was necessary to have the response period begin immediately following stimulus offset. This trait was later corrected for by adding 250 ms to response times so that the resultant response times were relative to stimulus onset. Subjects were requested to press one key with their dominant hand (as assessed by the Edinburgh inventory) when they saw a “human face”, and a different key with their other hand when they saw no face. This ensured that the subject was attentive to the task. Subjects were made aware that response time and accuracy were being recorded, and each participated in a preliminary training period. Response time and accuracy were recorded via Superlab on a Power Macintosh computer.

EEG Recording:

Continuous EEG recording was conducted simultaneously from a 32-electrode array at conventional 10-20 locations. Conduction between electrodes and the scalp was accomplished via electrolyte gel. Electrodes were initially referenced to mastoid electrodes, but were later re-referenced offline to an average of all electrodes. Electrooculogram (EOG) recordings were made from the supra- and sub-orbital ridge of the left eye and outer canthus of both eyes. Amplifier gain was set to 500, with filter settings of .15-30Hz. EEG signals were digitized at 500Hz. Impedances for most electrodes were below 5 ohms. The ground electrode was located midway between electrodes Fz and FCz.

The ERP system was designed such that the stimulus presentation computer sent a measured signal to the amplifier and EEG recording computer indicating stimulus category and onset time. EEG epochs were acquired beginning 200 ms before stimulus onset and ending 700 ms later, for a total of 350 data points per channel per epoch. Neuroscan software was used to identify peak negative amplitude, latency of that peak amplitude, and the area under the curve (AUC) during a 170-270 latency window for target electrodes.

Analysis:

As in other studies (e.g. Allison *et al*., 1999, Perrett *et al*. 1982) a stimulus specific potential was defined as one that was at least twice as large to that stimulus than to any other category of stimulus. For each category in each experiment, peak amplitude and latency data for each subject during the 170-270ms latency window were subjected to analysis of variance (ANOVA) to test for significant differences between stimulus categories. The area under curve for each condition was also calculated, but not subjected to ANOVA. For each subject, average response times and response accuracy were distilled from the raw Superlab data by a Qbasic program written for the task. (see Appendix 3) The manner in which the distillation was conducted, however, prevented analysis of variance for the behavioral data collected by Superlab.

EXPERIMENT 1:

Methods:

Three categories of images used by Allison *et al*. (1999c) were obtained and presented. Their description of these images is presented verbatim: “(i) Faces from books prepared by model agencies. (ii) Phase-scrambled faces created by computing a two-dimensional Fourier transform of each face, randomly scrambling its phase spectrum while preserving its frequency spectrum and then performing an inverse transform and correcting for luminance. (iii) Flowers obtained from digital stock images.” 24 male and 24 female images, 40 images of flowers, and 48 scrambled face images were presented in one block for a total of 136 stimuli. Because response times, as recorded by Superlab, were relative to stimulus *offset*, in this and all other experiments, 250 ms was added to all subject response times such that new response times were then relative to stimulus *onset*. Stimulus order was randomized and no image was repeated. Total experiment duration was approximately five minutes.

Results:

Faces evoked a significantly larger N170 in electrode P8 than flowers or scrambled faces *$(F(df\,2,33)=11.2, P<0.0002)$*. N170 latency was also differed

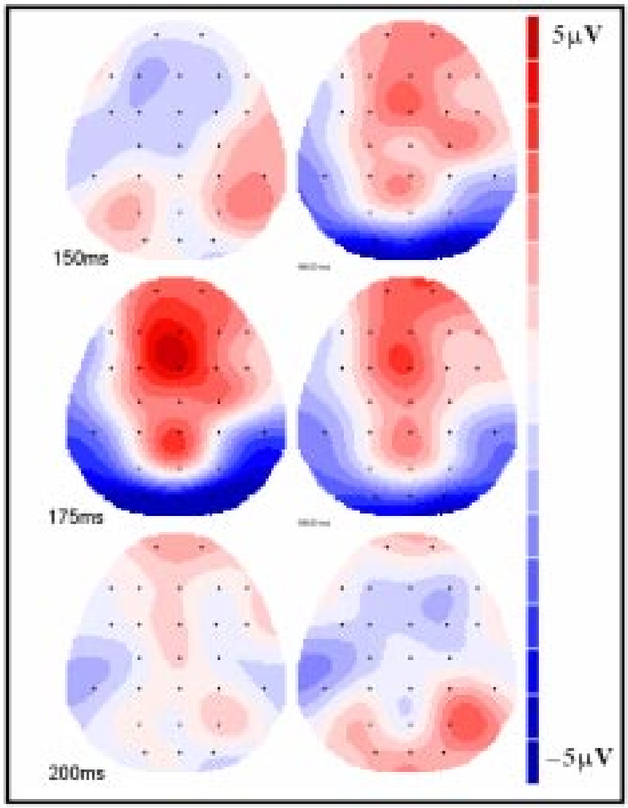


Figure 3. Voltage distribution of activity evoked by presentation of faces in Experiment 1. Red is representative of positive voltages, blue represents negative voltages. Note the negative activity in posterior temporal regions at 175 ms after face presentation.

significantly from latencies evoked by flowers or scrambled faces *(F(df 2,33) = 4.3, P<0.03)* (Figure 4) Behavioral results are reported in Figures 4 and show that subjects were above 90% accurate in their responses to each category. Average response times were longest for Scrambled Faces, followed by Flowers and finally Faces.

Discussion:

One of the things this experiment sought to determine was if N170 activity could be evoked when faces were designated as the target stimulus. The hypothesis was that if N170 activity is related to a mechanism that is cognitively impenetrable, the results for this experiment should be similar to results from other extracranial ERP experiments involving faces. Results from this experiment do indeed appear similar to results reported in Bentin *et al*. (1996) where non-face stimuli were designated targets. In those experiments, faces evoked

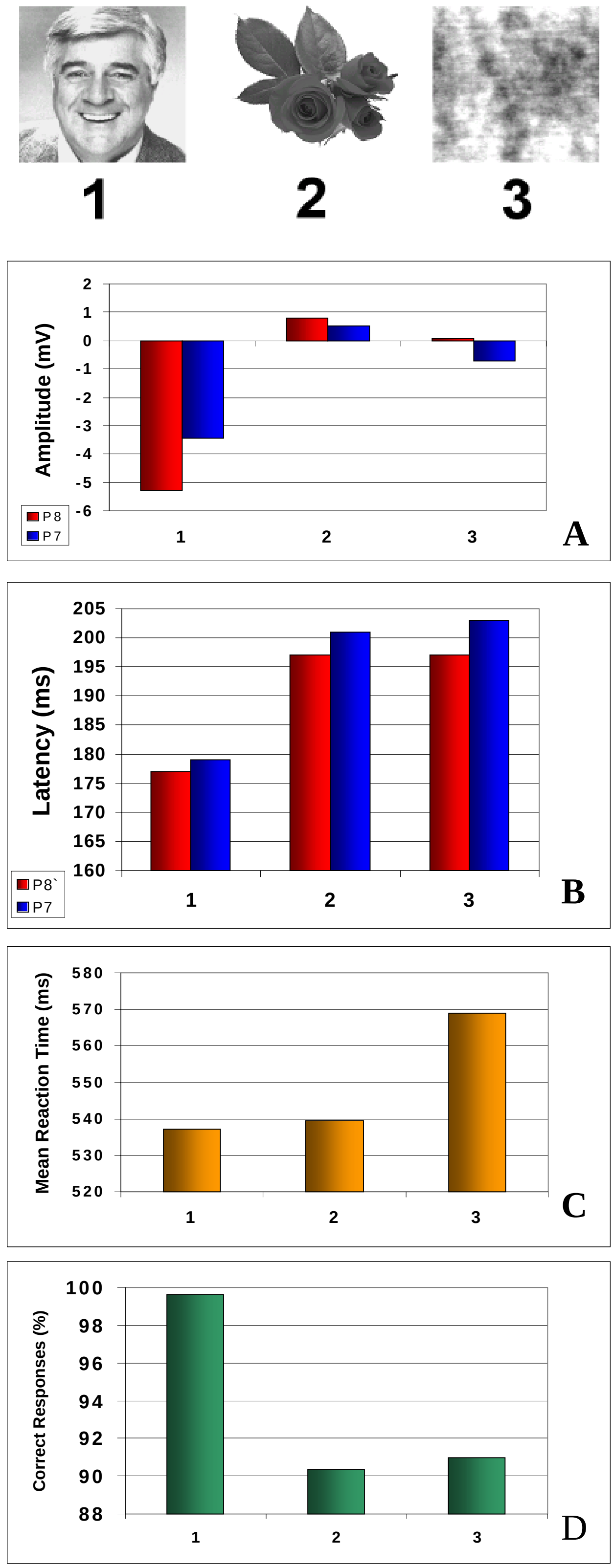


Figure 4. Summaries of Grand Averaged ERP and behavioral data for Experiment 1. (A) Amplitude; (B) Latency; (C) Mean Reaction Time; (D) Correct Response Scores. Note that ERP amplitudes for both electrode P7 and P8 are much larger in response to faces.

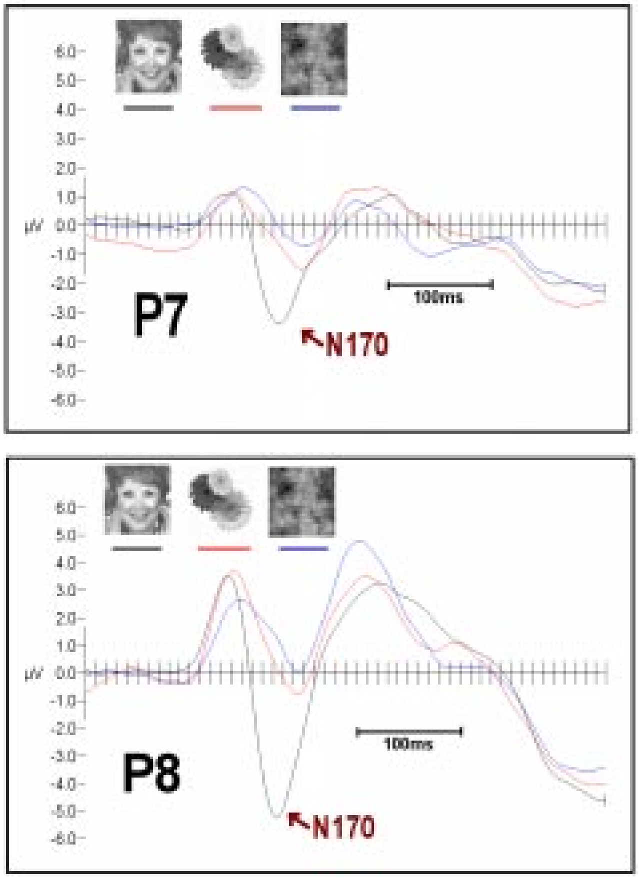


Figure 5. Examples of grand averaged waveforms recorded from stimuli in Experiment 1. Note that the waveform evoked by faces is much larger than those evoked by other stimuli, and is slightly larger in the right electrode (P8) than the left (P7).

similarly large (-4.07mV) grand-average amplitude deflections in similar electrode positions. Unfortunately, it is impossible to determine for these stimuli the difference, if any, between ERPs evoked when faces are designated targets versus when they are not, because that experiment was not carried out during this study. Nevertheless, Experiment 1 demonstrated that face-specific ERPs could be recorded from scalp electrodes when faces are designated target stimuli.

Behavioral data show that scrambled faces, which resemble no real objects, took longer to respond to than either photographs of faces or flowers. This could perhaps be because more processing time is necessary to evaluate images containing amorphous content. An ANOVA was not conducted to determine if the difference in reaction times was significant.

In addition to determining if N170 activity could be evoked when faces were designated the as target stimulus, another purpose of this experiment was to establish both behavioral and electrophysiological results that could be used for experiments 2 and 3. In that respect, this experiment possessed control stimuli for the other experiments because responses to blurred and noisy images were compared to those from this experiment.

EXPERIMENT 2

Methods:

Nine categories of stimuli were used in Experiment 2. Each image from the three categories in Experiment 1 (Faces, Scrambled faces, and Flowers) was subjected to three levels of blurring. Blurred images were produced in Adobe Photoshop by using a Gaussian blur filter with kernels of 10, 15, and 20 pixels. Doing so resulted in a stimulus set containing 408 images, which were presented in two consecutive blocks lasting approximately 7 to 8 minutes. Equal numbers of stimuli were randomly assigned to each block, and no image was repeated.

Results:

Results for Experiment 2 are summarized in Figure 6. There was no significant difference in N170 amplitude between unblurred faces of Experiment 1 and any of categories of blurred faces. Nor was there any significant difference in amplitude between any of the individual blur categories. There were, however, significant differences in N170 latencies between unblurred faces and blurred faces *($F(df\ 3,44)=3.6$, $p<0.02$)*, but no significant differences in latencies between individual blur categories (Figure 6b). The average area under curve (AUC) values for electrode P7 were comparable to the faces from experiment 1 in all the categories of this experiment, but in P8 only blurred face stimuli elicited AUC values comparable to faces

from Experiment 1. (see Appendix 2 for AUC data)

Behavioral results for Experiment 2 show that, on average, subject accuracy decreased as more high frequency information was removed from the images containing faces, a trend that was not evident in images containing flowers or scrambled faces. In the same respect, subject response time was on average higher as faces were blurred, a trend that was not found for the other images. Superlab behavioral data for each subject was averaged using a Qbasic program written for the task (see Appendix 3). Because they are simple averages, however, it would not be ethical to perform analysis of variance on these data. This is a notable drawback of this study in its present state, but is something that could be rectified by changing a few lines of code and re-parsing the files containing the behavioral data.

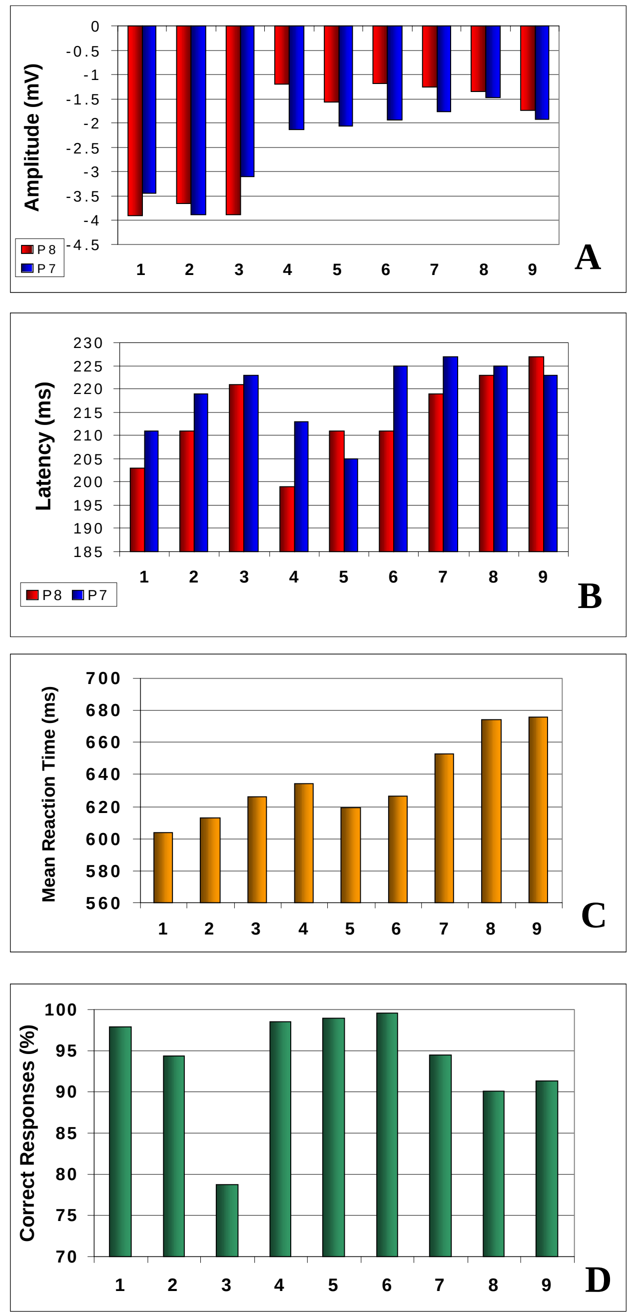


Figure 6. Summaries of Grand Averaged ERP and behavioral data for Experiment 2. (A) Amplitude; (B) Latency; (C) Mean Reaction Time; (D) Correct Response Scores. Notice the linear trend for both N170 latency and reaction times with increased blurring.

Discussion:

This experiment was conducted for several reasons. First, it was conducted to determine the effects of low-pass filtering of face stimuli on scalp recorded N170 activity. Allison *et al.*, (Allison *et al.*, (1999b))conducted a similar experiment investigating the effects of blurring on intracranially recorded ERPs. Although their experiment only used one level of blurring (using a kernel of 9 x 9 pixels—considerably less than the lowest value used in this experiment), the effects were similar in that they found significant differences in N200 latencies evoked by blurred and unblurred faces. In contrast, the intracranial experiment also found significant differences in N200 amplitudes evoked by blurred and unblurred faces, a trait that was not evident in this data. One potential reason for this discrepancy is the fact that intracranial electrodes routinely record deflections of over 100mV while potentials recorded via scalp electrodes are smaller due to the insulating effects of dura matter and the skull.

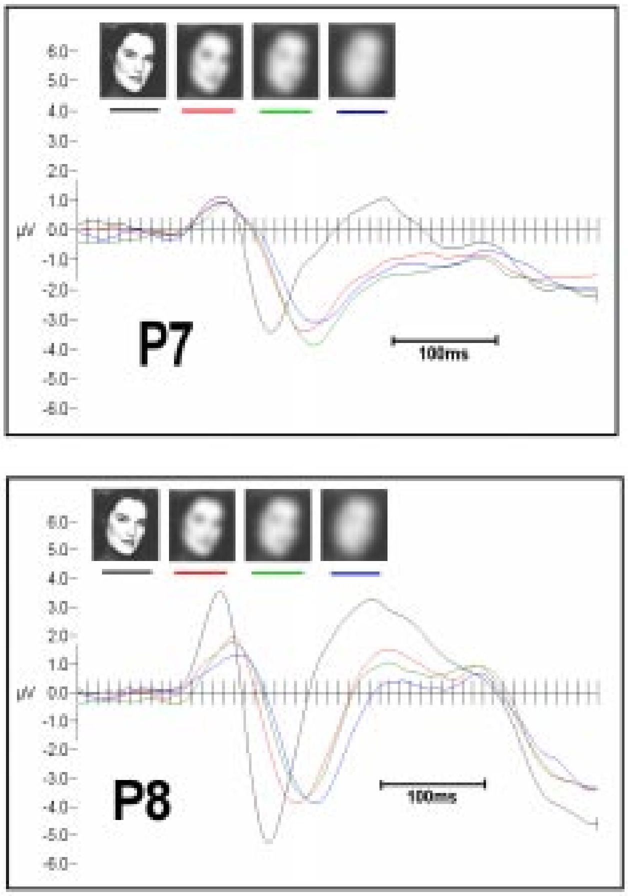


Figure 7. Grand averaged waveforms evoked by different levels of blurring in left (P7) and right (P8) electrodes. Notice that N170 latency increases as blurring is increased.

The second reason this experiment was conducted was to determine if the behavioral reports of subjects corresponded to electrophysiological data recorded at the scalp. Experiment 1 established that face-specific N170 activity is still present when subjects are instructed to search for faces. Experiment 2 extended on this initiative by presenting faces that had been heavily blurred in an attempt to foil the face detection mechanisms of the brain. In one respect, the experiment succeeded in doing so, as target detection accuracy dropped with increased blurring. Interestingly, though, while subject accuracy dropped to 78% for faces that had undergone the highest level of blurring, the waveforms evoked by these images still qualified as face specific. Indeed, the amplitudes of the N170s evoked by blurred faces were not significantly different than amplitudes found by Experiment 1. It is important to point out that all epochs from a given category were averaged together, without regard to how the subject responded. This is a serious flaw in analysis that will be returned to in the General Discussion. What *were* different, however were the latencies the peaks of those N170s evoked by blurry faces. These data suggest that it takes whatever neural mechanisms that give rise to this activity longer to process faces missing higher spatial frequencies, which in turn suggests that these spatial frequencies are important for the rapid detection of faces. It is important to mention that PET and fMRI studies would not be capable of observing the temporal traits found here.

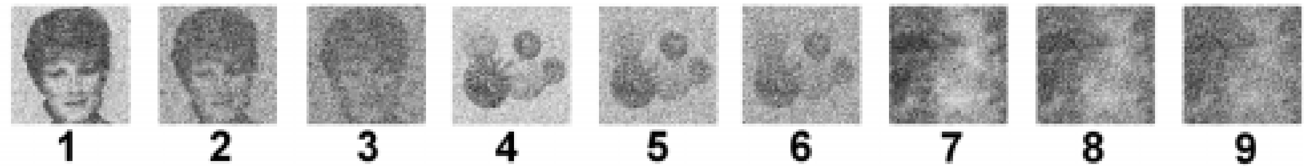
EXPERIMENT 3

Methods:

The design of Experiment 3 was identical to that of Experiment 2, except that rather than applying a blur filter, random visual noise was applied to the images from Experiment 1. A Qbasic program (Appendix 3) was written to replace random pixels with a gray-scale pixel of random luminosity, and images from Experiment 1 with 50%, 60%, and 70% of visual noise were generated. This again resulted in 408 images, which were presented in two blocks. No images were repeated.

Results:

None of the waveforms evoked by face containing stimuli qualified as face-specific, and no N170 activity was observed in any of the other stimulus categories. ANOVA was nonetheless carried out on peak negative amplitudes and related latencies and found that amplitudes evoked by noisy faces differed significantly from N170 amplitudes evoked by faces in Experiment 1 ($F(df\ 3,44) = 11.5$, $p<0.00002$). Amplitudes of waveforms evoked by the three categories of noisy faces did not differ significantly. Latencies between Experiment 1 N170's and waveforms evoked by noisy faces did have significant differences ($F(df\ 3,44 = 13.7$, $p<0.000002$), but dif-



ferences between the three categories of noisy faces were insignificant.

Behavioral results were similar to those in Experiment 2; subject accuracy fell and response time rose as face images were modified. Subject accuracy did not decrease as flower containing images were pixelated, and increased as scrambled face containing images were pixelated. Reaction times, on average, rose as face and flower containing images were pixelated, but fell as scrambled face containing images became noisier.

Discussion:

The aims and design of Experiment 3 were similar to that of the preceding experiment. It was conducted first to determine the effects, if any, of image manipulation on N170 activity, and second to determine if behavioral reports corresponded to EEG activity. With regard to both initiatives, it is meaningful that noisy faces failed to elicit N170. First, it suggests that there is some threshold of activation that requires less than 50% visual noise for N170 to be observed. Second, given that even for the least noisy faces, for which behavioral reports were 95% correct, no N170 was recorded, these data suggest N170 activity *does not* necessarily correlate with behavioral reports. In this respect, the overarching hypothesis for this study—that electrophysiological activity would consistently correlate with the behavioral reports of subjects—must be rejected.

There are at least two possible scenarios that could give rise to the discrepancy between these behavioral and scalp recorded electrophysiological data. First, the absence of N170 activity could be due to a masking effect brought about by the activity of neighboring cortical tissue. In this scenario, the mechanisms that give rise to N170 would operate as before, but recording N170 via scalp electrodes would be hindered. A cursory visual inspection of electrodes other than P7 and P8 did not reveal any outstanding abnormalities; record-

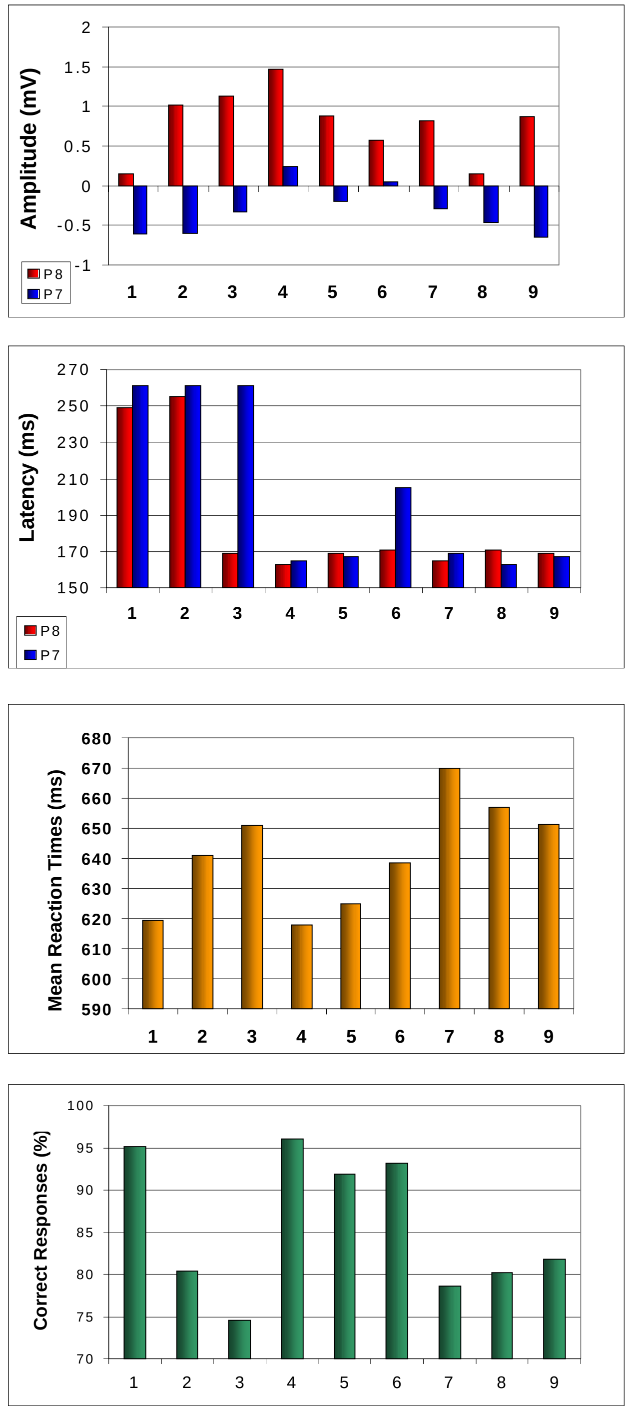


Figure 6. Summaries of Grand Averaged ERP and behavioral data for Experiment 3. (A) Amplitude; (B) Latency; (C) Mean Reaction Time; (D) Correct Response Scores. Note that none of the amplitudes qualified as face-specific.

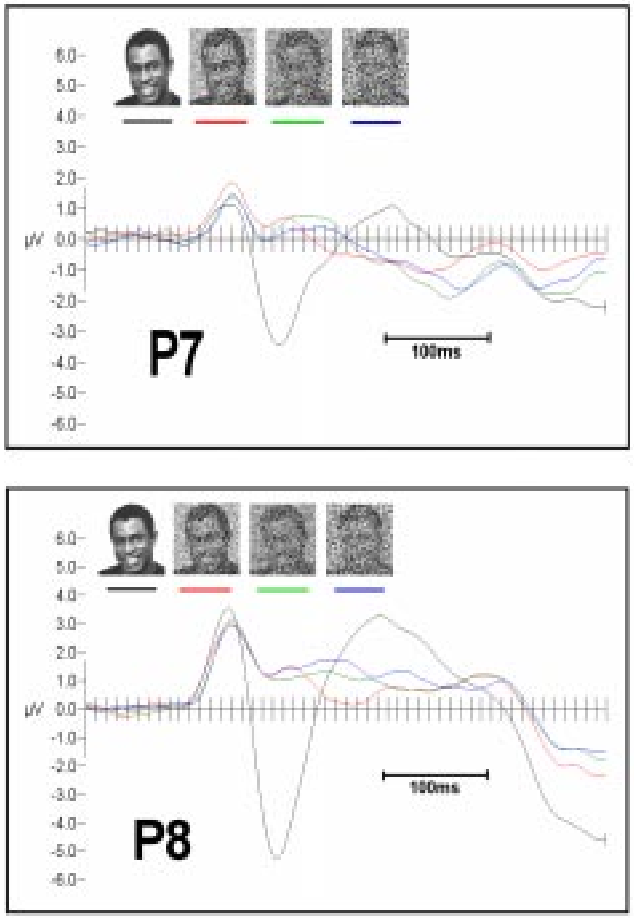


Figure 7. Grand averaged waveforms evoked by different levels of noise addition in left (P7) and right (P8) electrodes. None of the waveforms elicited by face containing images in Experiment 3 qualified as face-specific.

ings for electrodes neighboring P7 and P8 appeared to be similar to those recorded during the other two experiments. A more detailed analysis of those neighboring electrodes might provide evidence in support of this hypothesis. There are computational tools that can be used on scalp EEG data to suggest the anatomical origins of electrical activity, and it is possible that analysis employing these tools would reveal activity that interfered with N170 recordability. Further, the stimuli from this experiment could be shown to subjects undergoing magnetic resonance scanning, where recording would not be affected by these considerations.

In the second scenario, the absence of N170 could really be indicative of inactivity of presumed origin of N170, the fusiform face area. This would suggest that some alternate mechanisms processed the image and provided the higher cognitive neural areas with the information that led to the correct behavioral responses. It may be the case that the mechanisms that give rise to N170 are mainly responsive to relatively low spatial frequencies. This last possibility is considered in the General Discussion, to which we now turn.

GENERAL DISCUSSION:

This study sought to accomplish two overarching objectives: to further delineate the response properties of face-selective electrophysiological activity as recorded via non-invasive scalp electrodes in normal subjects, and to investigate the relationship between this activity and the behavioral reports of subjects. The results show that N170 activity is contingent on the amount of visual information available to the brain. Whereas N170 is delayed but not diminished by heavy blurring, it is abolished if a face-containing image is masked by even 50% visual noise. The results also show that N170 activity is not an accurate predictor of higher-level perception; N170 was sometimes absent when subjects accurately detected faces.

While it was not possible during the course of this study to statistically compare response times and N170 latencies for Experiment 2, it should be noted that both appear to follow a directional trend; for increased blurring, average response time and N170 latencies increase. Furthermore, reaction times and N170 latencies appeared to increase by comparable amounts as blurring was increased. This apparent covariance could be determined qualitatively by returning to the raw behavioral data, something that time prohibited in this study. If covariance were established, it would suggest that for images lacking high spatial frequencies there is increased processing strain on the visual system. The relative contributions of high and low spatial frequencies to face detection cannot be extracted from these data, but there is reason to believe that while blurring may place increased strain on the visual system, high-pass filtering would do so more. Allison, *et al.*, (Allison, *et al.*, 1999b), while conducting intracranial recordings, found that N200 amplitude was more diminished by high-pass filtering than blurring. In addition, N200 came on average 34 ms later in response to high-pass filtered faces. Fiorentini (Fiorentini *et al.*, 1983) in behavioral experiments found that subjects were better at recognizing familiar faces that had been blurred than cartoon (high-pass) versions of familiar faces. A logical future direction would be to investigate the relative contributions of high- and low- spatial frequency content to face *detection* (versus recognition) both behaviorally and with regard to N170. Doing so may show that face detection mechanisms in the brain prefer low spatial frequencies to high.

It is not obvious what conclusions to draw from data collected in Experiment 3. While it is apparent enough that noisy faces did not evoke N170, it is not as obvious why this is so. If the visual system does indeed prefer low spatial frequencies in performing face detection, (as could be inferred from Fiorentini *et al*,. 1983) then the introduction of overlying high frequency noise would diminish the efficacy of those mechanisms involved in face detection. It is the case that the most incorrect responses registered during the course of this study were in response to face stimuli in Experiment 3, although there is no solid basis for comparing accuracy between these experiments. As covered in the Discussion for Experiment 3, there are several possible causes for the absence of N170 for noisy faces. Likewise, there are several avenues, though costly, for attempting to resolve the issue.

What *is* clear from Experiment 3 is that subjects could accurately detect faces even when no N170 was observed. Indeed, accuracy for the least noisy faces was above 95%, and yet amplitude and AUC values for that category were comparable to those evoked by flower stimuli from Experiment 1! While this may be due to issues involved with recording from scalp electrodes, it may be the case that there are multiple and parallel pathways by which face detection may be accomplished. It could be that faces in Experiment 3 were detected using a more general object detection mechanism. Without more information, one can but speculate.

FUTURE DIRECTIONS:

One drawback of this study was that subjects were required to search for faces in every image presented, and so there was no opportunity to compare these recordings with recordings made when faces were not targets. In order to fully explore the idea that the neural substrate that gives rise to N170 is autonomous and cognitively impenetrable, it would be necessary to compare waveforms evoked under both circumstances: when faces were targets and non-targets.

There are a variety of other image manipulations that I would like to have used to more thoroughly investigate the response properties of N170. One obvious image manipulation that could be performed is high-pass filtering. If, as hypothesized in the General Discussion, the neural substrate giving rise to N170 does indeed prefer low spatial frequencies, then I would expect N170 to be substantially attenuated.

It is important to mention that there are several other forms of analysis that could be performed on the data collected in this study. First, analysis could be performed on subject reaction times and N170 latency to investigate the possibility of significant correlation between the two. Second, the continuous EEG data could be re-epoched with windows longer than 500 ms. This would afford the opportunity to investigate other face-specific waveforms that may come after N170. Third, one could investigate gender-based differences in both behavioral and electrophysiological data. Lastly, and most importantly, it is worth averaging EEG data from Experiment 3 only for those trials where the subject made the correct behavioral response. While the signal-to-noise ratio for ERPs would rise substantially (because the number of trials available for averaging would drop), this step is crucial for determining if N170 is really absent when subjects reported seeing faces.

CONCLUDING REMARKS:

This study has shown that face specific extracranial N170 activity can be recorded even when subjects are actively attentive to the facial content of stimuli, further enhancing the supposition that

N170 reflects activity of a cognitively impenetrable module in extrastriate cortex. It has shown that removal of higher spatial frequencies increases both N170 latency and subject response times, implying that the brain needs more time to process these images. Lastly, it has shown that, for noisy faces, behavioral accounts and electrophysiological recordings do not correlate. If these electrophysiological data are not merely an artifact of scalp-based recording, they suggest that the brain has more than one mechanism for detecting faces.

This research fulfills part of the requirements for Division III at Hampshire College. I would like to thank my advisors on this project, Drs. Neil Stillings and Joanna Morris, the Howard Hughes Medical Institute, and Dr. Truett Allison for supplying images used in this study.

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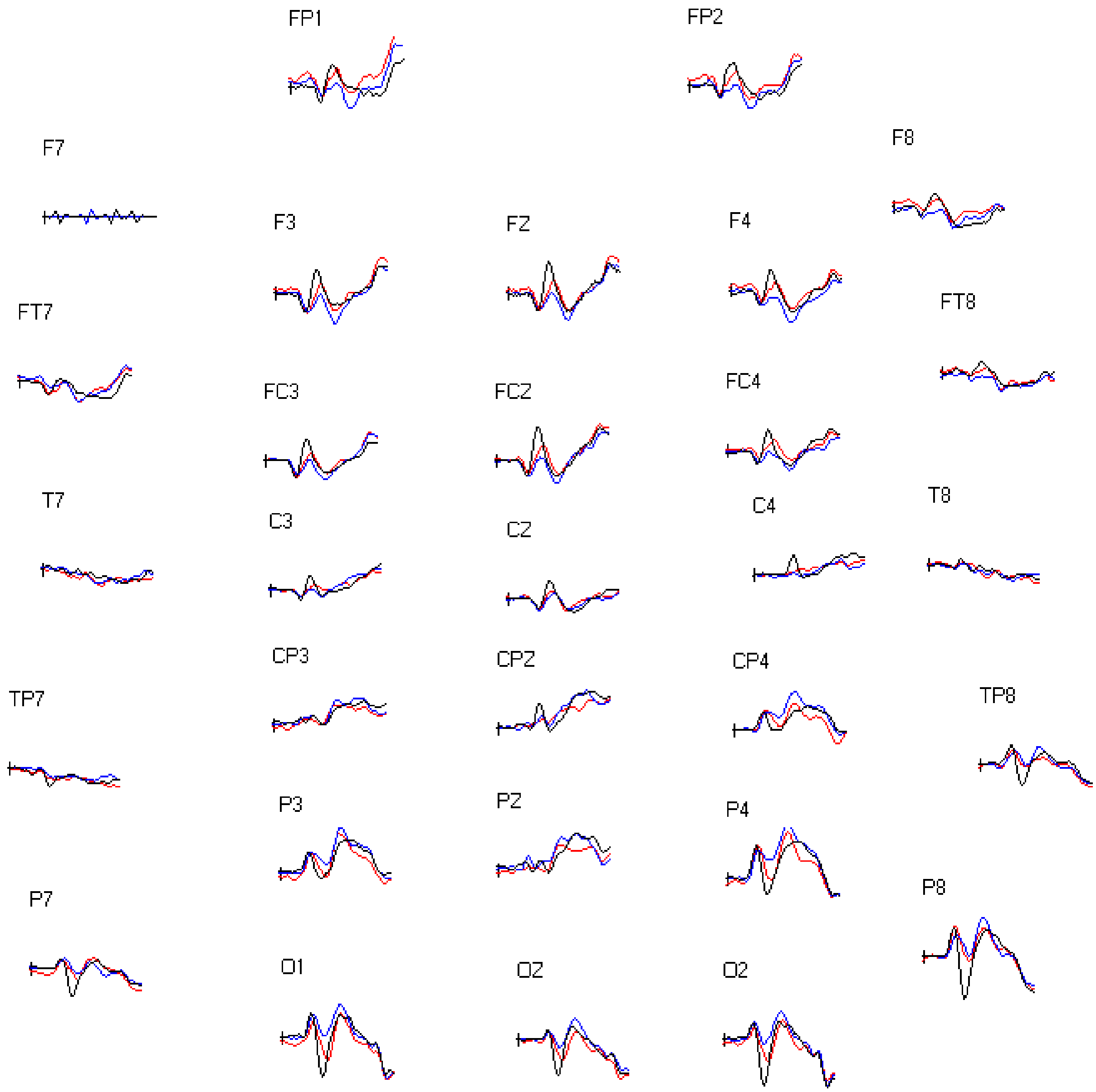
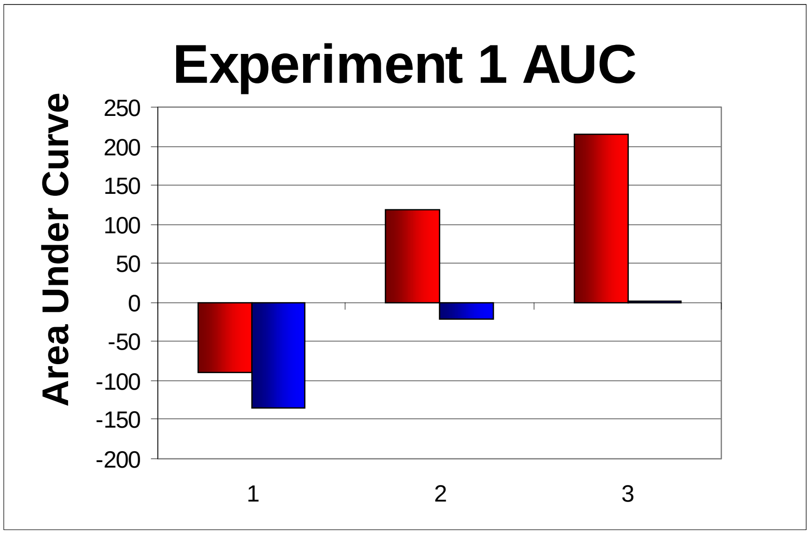
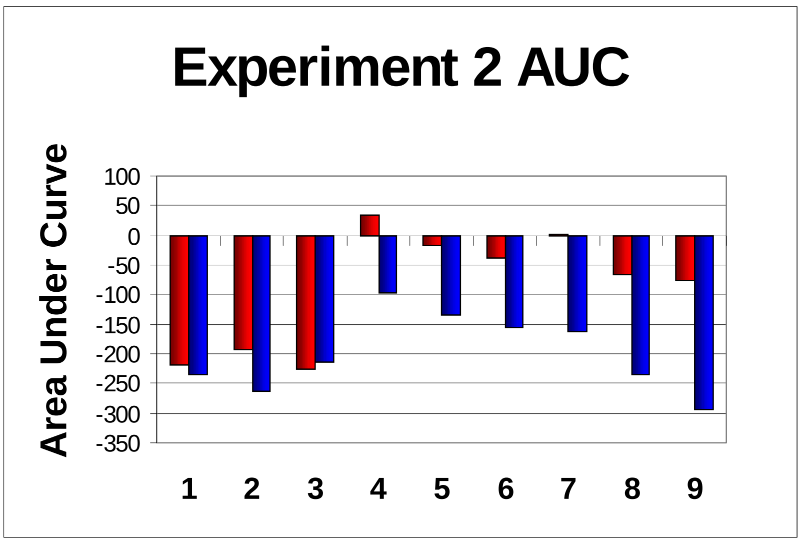
Tranel, D., & Damasio, A (1985). Knowledge without awareness: An autonomic index of facial recognition by prosopagnosics. Science, 228, 1453-1454.

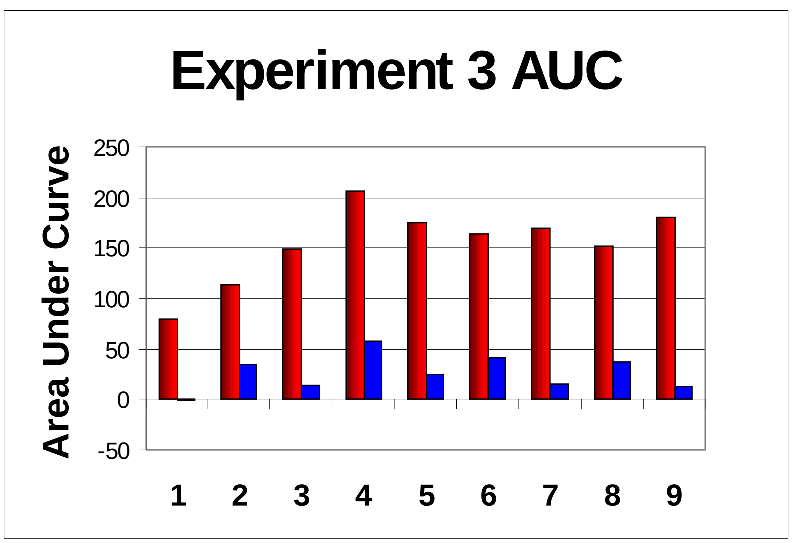
Appendix 1: 32 electrode montage for Experiment 1. Recordings from electrode F7 were corrupted.



Appendix 2: Area Under Curve (AUC) data for all experiments.







Appendix 3: Qbasic computer code written for this study.

Visual noise adder:

```
‘this program will add visual noise to .ps image files
begin.noise.level = .5
end.noise.level = 1
noise.step = .05

                                ‘ this is for the number of iterations
FOR runn = begin.noise.level TO end.noise.level STEP noise.step
file.name = file.name + 1
RANDOMIZE TIMER

in.ps.file.name$ = “scull.ps”
out.pat.file.name$ = “noise” + STR$(file.name) + “.ps”  ‘in future name file
according to how much noise
‘+++++++++++++++++++++++++++++++++++++++++++++++++++++++end parameter def sect
OPEN in.ps.file.name$ FOR INPUT AS #1
OPEN out.pat.file.name$ FOR OUTPUT AS #2

FOR i = 1 TO 26     ‘this is for the header info.
INPUT #1, t$
PRINT #2, t$
NEXT i

WHILE MID$(t$, 1, 1) <> “s”                                ‘end of data
INPUT #1, t$
RANDOMIZE TIMER

        IF MID$(t$, 1, 1) = “s” THEN GOTO skip.table

FOR i = 1 TO LEN(t$) STEP 2

        cin$ = MID$(t$, i, 2)

        IF RND > .5 THEN r1$ = CHR$(49 + INT(RND * 8)) ELSE r1$ = CHR$(97 +
INT(RND * 6))
        IF RND > .5 THEN r2$ = CHR$(49 + INT(RND * 8)) ELSE r2$ = CHR$(97 +
INT(RND * 6))
        random.value$ = r1$ + r2$

        IF RND < runn THEN PRINT #2, random.value$;  ELSE PRINT #2, cin$;

NEXT i

        lines = lines + 1

WEND

skip.table:
PRINT #2,
PRINT #2, t$              ‘this is for writing the showpage
FOR i = 1 TO 3            ‘this is for writing the footer
INPUT #1, t$
PRINT #2, t$
```

```
NEXT i



PRINT pixels, lines

CLOSE #1
PRINT out.pat.file.name$
CLOSE #2
```

Superlab script generator:

```
'this qbasic program will generate a text file for a superlab experiment

stimuli = 408  'markstim must be less than 254
stim.pres.time$ = "250"
DIM fixa.dura$(stimuli)

RANDOMIZE TIMER

OPEN "test.doc" FOR OUTPUT AS #1
PRINT #1, "* SuperLab v1.5 experiment file."
PRINT #1, ""
PRINT #1, "#Script-Version"; CHR$(9); "7"
PRINT #1, "#Background-Color"; CHR$(9); "65535"; CHR$(9); "65535"; CHR$(9);
"65535"; ""
PRINT #1, "#Input-Method"; CHR$(9); "gnrc"; CHR$(9); "0"; CHR$(9); "0"; CHR$(9);
"0"
PRINT #1, "#Timing-Method"; CHR$(9); "tmr1"
PRINT #1, ""


'~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~EVENTS
PRINT #1, "#Events"
PRINT #1, ""
PRINT #1, "*  Event        Event   Response                Terminate       Cor-
rect"
PRINT #1, "** Name Type     Action Duration           On   Response"
PRINT #1, ""
PRINT #1, "trig"; CHR$(9); "dout"; CHR$(9); "1"; CHR$(9); "0"; CHR$(9); "1";
CHR$(9); "0"
PRINT #1, "zero"; CHR$(9); "dout"; CHR$(9); "1"; CHR$(9); "0"; CHR$(9); "1";
CHR$(9); "0"

i = 0
FOR i = 1 TO stimuli

        fixa$ = "fix" + STR$(i): MID$(fixa$, 4, 1) = "a"
        mark$ = "mar" + STR$(i): MID$(mark$, 4, 1) = "k"
        stim$ = "sti" + STR$(i): MID$(stim$, 4, 1) = "m"
        resp$ = "res" + STR$(i): MID$(resp$, 4, 1) = "p"

fixa.dura = INT(1000 + (RND * 1000))    'random fixation duration in ms. (1-2sec)
fixa.dura$ = STR$(fixa.dura)
fixa.dura$(i) = MID$(fixa.dura$, 2, (LEN(fixa.dura) - 0))
```

```
PRINT #1, fixa$; CHR$(9); “visl”; CHR$(9); “1”; CHR$(9); fixa.dura$(i); CHR$(9);
“1”; CHR$(9); “0”
PRINT #1, mark$; CHR$(9); “dout”; CHR$(9); “1”; CHR$(9); “0”; CHR$(9); “1”;
CHR$(9); “0”
PRINT #1, stim$; CHR$(9); “visl”; CHR$(9); “1”; CHR$(9); “250”; CHR$(9); “1”;
CHR$(9); “0”
PRINT #1, resp$; CHR$(9); “visl”; CHR$(9); “2”; CHR$(9); “0”; CHR$(9); “1”;
CHR$(9); “0”

NEXT i

‘~~~~~~~~~~~~~~~~~~~~~~~~~~~`VISUAL EVENT
PRINT #1, “”
PRINT #1, “#Visual”
PRINT #1, “*  Event        File    Dir     Vert    Horiz   Vert    Horiz   Misc.
Play    Lead     “
PRINT #1, “** Name Name    ID      Size    Size    Pos.    Pos.    Flags   Time
Time    Reserved”

i = 0
FOR i = 1 TO stimuli

        fixa$ = “fix” + STR$(i): MID$(fixa$, 4, 1) = “a”
        stim$ = “sti” + STR$(i): MID$(stim$, 4, 1) = “m”
        resp$ = “res” + STR$(i): MID$(resp$, 4, 1) = “p”

PRINT #1, fixa$; CHR$(9); “fixate.pct”; CHR$(9); “0”; CHR$(9); “0”; CHR$(9); “0”;
CHR$(9); “0”; CHR$(9); fixa.dura$(i); CHR$(9); “2342”; CHR$(9); “113”; CHR$(9);
“0”; CHR$(9); “0”
PRINT #1, stim$; CHR$(9); stim$ + “.pct”; CHR$(9); “0”; CHR$(9); “0”; CHR$(9);
“0”; CHR$(9); “0”; CHR$(9); stim.pres.time$; CHR$(9); “2342”; CHR$(9); “113”;
CHR$(9); “0”; CHR$(9); “0”
PRINT #1, resp$; CHR$(9); “blank.pct”; CHR$(9); “0”; CHR$(9); “0”; CHR$(9); “0”;
CHR$(9); “0”; CHR$(9); “0”; CHR$(9); “1062”; CHR$(9); “-1”; CHR$(9); “0”;
CHR$(9); “0”
NEXT i


‘~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~DIGITAL OUTPUT
PRINT #1, “”
PRINT #1, “#Digital-Output”
PRINT #1, “*  Event                Card     Byte   Output          Inter-Pulse
“
PRINT #1, “** Name Slot    Type    Offset  Lines   Duration         Interval
Repeat  Reserved”
PRINT #1, “trig”; CHR$(9); “1”; CHR$(9); “5”; CHR$(9); “0”; CHR$(9); “255”;
CHR$(9); “20”; CHR$(9); “10”; CHR$(9); “1”; CHR$(9); “0”
PRINT #1, “zero”; CHR$(9); “1”; CHR$(9); “5”; CHR$(9); “0”; CHR$(9); “0”;
CHR$(9); “20”; CHR$(9); “10”; CHR$(9); “1”; CHR$(9); “0”

FOR i = 1 TO stimuli           ‘here is where we set the marker to be passed to
‘acquire’
                               ‘these ranges are specific to my stimulus set

        IF i >= 0 AND i <= 144 THEN marker = (i MOD 3) + 1   ‘faces
      IF i >= 145 AND i <= 264 THEN marker = (i MOD 3) + 4   ‘flowers
```

```
      IF i >= 265 AND i <= 408 THEN marker = (i MOD 3) + 7   'scrambled faces

'a reassignment table for a more intiutive marking scheme:

       IF marker = 2 THEN marker = 1: GOTO skip.table 'level 1 face
       IF marker = 3 THEN marker = 2: GOTO skip.table 'level 2 face
       IF marker = 1 THEN marker = 3: GOTO skip.table 'level 3 face
       IF marker = 5 THEN marker = 4: GOTO skip.table 'level 1 flower
       IF marker = 6 THEN marker = 5: GOTO skip.table 'level 2 flower
       IF marker = 4 THEN marker = 6: GOTO skip.table 'level 3 flower
       IF marker = 8 THEN marker = 7: GOTO skip.table 'level 1 scrambled face
       IF marker = 9 THEN marker = 8: GOTO skip.table 'level 2 scrambled face
       IF marker = 7 THEN marker = 9: GOTO skip.table 'level 3 scrambled face



skip.table:
marker$ = MID$(STR$(marker), 2, 1)

mark$ = "mar" + STR$(i): MID$(mark$, 4, 1) = "k"
PRINT #1, mark$; CHR$(9); "1"; CHR$(9); "5"; CHR$(9); "0"; CHR$(9); marker$;
CHR$(9); "20"; CHR$(9); "10"; CHR$(9); "1"; CHR$(9); "0"
NEXT i

'~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~TRIALS
PRINT #1, ""
PRINT #1, "#Trials"
PRINT #1, "* Codes:"
FOR i = 1 TO stimuli
        trial$ = "tria" + STR$(i): MID$(trial$, 5, 1) = "l"
PRINT #1, trial$
NEXT i

'~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~BLOCKS
PRINT #1, ""
PRINT #1, "#Blocks"
PRINT #1, "block1"; CHR$(9); "1"; CHR$(9); "0"


'~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~BLOCK-TRIALS
PRINT #1, ""
PRINT #1, "#Block-Trials"
PRINT #1, "block1"; CHR$(9);
FOR i = 1 TO stimuli
        trial$ = "tria" + STR$(i): MID$(trial$, 5, 1) = "l"
PRINT #1, trial$; CHR$(9);
NEXT i

'~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~TRIAL-EVENTS
PRINT #1, ""
PRINT #1, ""
PRINT #1, "#Trial-Events"
FOR i = 1 TO stimuli
        trial$ = "tria" + STR$(i): MID$(trial$, 5, 1) = "l"
        fixa$ = "fix" + STR$(i): MID$(fixa$, 4, 1) = "a"
        mark$ = "mar" + STR$(i): MID$(mark$, 4, 1) = "k"
        stim$ = "sti" + STR$(i): MID$(stim$, 4, 1) = "m"
```

```
        resp$ = “res” + STR$(i): MID$(resp$, 4, 1) = “p”
PRINT #1, trial$; CHR$(9); “trig”; CHR$(9); “zero”; CHR$(9); fixa$; CHR$(9);
mark$; CHR$(9); stim$; CHR$(9); resp$
NEXT i


CLOSE #1
PRINT “test. written”
END
```

Sample Behavioral data distiller:

```
‘this program will tally response times and accuracy for my div3 experiment.

FOR sub.num = 1 TO 12    ‘twelve different files per subject, twelve different
files per experiment

 IF sub.num = 1 THEN OPEN “c:\data\desk\b_data\s01\b.txt” FOR INPUT AS #1: OPEN
“c:\data\desk\b_data\s01.d” FOR OUTPUT AS #2
 IF sub.num = 2 THEN OPEN “c:\data\desk\b_data\s02\b.txt” FOR INPUT AS #1: OPEN
“c:\data\desk\b_data\s02.d” FOR OUTPUT AS #2
 IF sub.num = 3 THEN OPEN “c:\data\desk\b_data\s03\b.txt” FOR INPUT AS #1: OPEN
“c:\data\desk\b_data\s03.d” FOR OUTPUT AS #2
 IF sub.num = 4 THEN OPEN “c:\data\desk\b_data\s04\b.txt” FOR INPUT AS #1: OPEN
“c:\data\desk\b_data\s04.d” FOR OUTPUT AS #2
 IF sub.num = 5 THEN OPEN “c:\data\desk\b_data\s05\b.txt” FOR INPUT AS #1: OPEN
“c:\data\desk\b_data\s05.d” FOR OUTPUT AS #2
 IF sub.num = 6 THEN OPEN “c:\data\desk\b_data\s06\b.txt” FOR INPUT AS #1: OPEN
“c:\data\desk\b_data\s06.d” FOR OUTPUT AS #2
 IF sub.num = 7 THEN OPEN “c:\data\desk\b_data\s07\b.txt” FOR INPUT AS #1: OPEN
“c:\data\desk\b_data\s07.d” FOR OUTPUT AS #2
 IF sub.num = 8 THEN OPEN “c:\data\desk\b_data\s08\b.txt” FOR INPUT AS #1: OPEN
“c:\data\desk\b_data\s08.d” FOR OUTPUT AS #2
 IF sub.num = 9 THEN OPEN “c:\data\desk\b_data\s09\b.txt” FOR INPUT AS #1: OPEN
“c:\data\desk\b_data\s09.d” FOR OUTPUT AS #2
 IF sub.num = 10 THEN OPEN “c:\data\desk\b_data\s10\b.txt” FOR INPUT AS #1: OPEN
“c:\data\desk\b_data\s10.d” FOR OUTPUT AS #2
 IF sub.num = 11 THEN OPEN “c:\data\desk\b_data\s11\b.txt” FOR INPUT AS #1: OPEN
“c:\data\desk\b_data\s11.d” FOR OUTPUT AS #2
 IF sub.num = 12 THEN OPEN “c:\data\desk\b_data\s12\b.txt” FOR INPUT AS #1: OPEN
“c:\data\desk\b_data\s12.d” FOR OUTPUT AS #2

   i = 0
   FOR i = 1 TO 7: INPUT #1, t$: NEXT i    ‘this trims the header info.

   ‘+++++++++++++++++++++++++++++++++++++
   WHILE MID$(t$, 1, 5) = “trial”        ‘while there are still rows of stimuli
to tally do...

        trial.num$ = (MID$(t$, 6, 3)) ‘extracts stimulus #
        trial.num = VAL(trial.num$)
        total.trial.num = total.trial.num + 1

      tab.num = 0           ‘resets tab num (used to seperate fields in sl
results.out
                     ‘+++++++++++++++++++++++++++++++++++++++++++++++=
```

```
      FOR column = 1 TO 70  'this loop is necessary to extract response value &
                            'reaction time from tab deliniated format

         IF MID$(t$, column, 1) = CHR$(9) THEN tab.num = tab.num + 1

         IF tab.num = 3 THEN response.value$ = MID$(t$, column, 1)
         IF tab.num = 4 THEN response.time = VAL(MID$(t$, column + 2, 3)):
response.num = response.num + 1

                      '++++++++++++++++++++++++++++++++++++++++++++++++++
      NEXT column

  IF trial.num >= 0 AND trial.num <= 144 THEN marker = (trial.num MOD 3) + 1
'faces
  IF trial.num >= 145 AND trial.num <= 264 THEN marker = (trial.num MOD 3) + 4
'flowers
  IF trial.num >= 265 AND trial.num <= 408 THEN marker = (trial.num MOD 3) + 7
'scrambled faces



       IF marker = 2 THEN total.rt.FACE.1 = total.rt.FACE.1 + response.time:
total.FACE.1 = total.FACE.1 + 1: GOTO skip.table'level 1 face
       IF marker = 3 THEN total.rt.FACE.2 = total.rt.FACE.2 + response.time:
total.FACE.2 = total.FACE.2 + 1: GOTO skip.table'level 2 face
       IF marker = 1 THEN total.rt.FACE.3 = total.rt.FACE.3 + response.time:
total.FACE.3 = total.FACE.3 + 1: GOTO skip.table'level 3 face
       IF marker = 5 THEN total.rt.FLOWER.1 = total.rt.FLOWER.1 + response.time:
total.FLOWER.1 = total.FLOWER.1 + 1: GOTO skip.table'level 1 flower
       IF marker = 6 THEN total.rt.FLOWER.2 = total.rt.FLOWER.2 + response.time:
total.FLOWER.2 = total.FLOWER.2 + 1: GOTO skip.table'level 2 flower
       IF marker = 4 THEN total.rt.FLOWER.3 = total.rt.FLOWER.3 + response.time:
total.FLOWER.3 = total.FLOWER.3 + 1: GOTO skip.table'level 3 flower
       IF marker = 8 THEN total.rt.SCFACE.1 = total.rt.SCFACE.1 + response.time:
total.SCFACE.1 = total.SCFACE.1 + 1: GOTO skip.table'level 1 scrambled face
       IF marker = 9 THEN total.rt.SCFACE.2 = total.rt.SCFACE.2 + response.time:
total.SCFACE.2 = total.SCFACE.2 + 1: GOTO skip.table'level 2 scrambled face
       IF marker = 7 THEN total.rt.SCFACE.3 = total.rt.SCFACE.3 + response.time:
total.SCFACE.3 = total.SCFACE.3 + 1: GOTO skip.table'level 3 scrambled face
skip.table:

       IF marker = 2 AND response.value$ = "k" THEN face.1.correct =
face.1.correct + 1
       IF marker = 2 AND response.value$ = "d" THEN face.1.incorrect =
face.1.incorrect + 1
       IF marker = 3 AND response.value$ = "k" THEN face.2.correct =
face.2.correct + 1
       IF marker = 3 AND response.value$ = "d" THEN face.2.incorrect =
face.2.incorrect + 1
       IF marker = 1 AND response.value$ = "k" THEN face.3.correct =
face.3.correct + 1
       IF marker = 1 AND response.value$ = "d" THEN face.3.incorrect =
face.3.incorrect + 1
       IF marker = 5 AND response.value$ = "d" THEN flower.1.correct =
flower.1.correct + 1
       IF marker = 5 AND response.value$ = "k" THEN flower.1.incorrect =
flower.1.incorrect + 1
```

```
       IF marker = 6 AND response.value$ = “d” THEN flower.2.correct =
flower.2.correct + 1
       IF marker = 6 AND response.value$ = “k” THEN flower.2.incorrect =
flower.2.incorrect + 1
       IF marker = 4 AND response.value$ = “d” THEN flower.3.correct =
flower.3.correct + 1
       IF marker = 4 AND response.value$ = “k” THEN flower.3.incorrect =
flower.3.incorrect + 1
       IF marker = 8 AND response.value$ = “d” THEN scface.1.correct =
scface.1.correct + 1
       IF marker = 8 AND response.value$ = “k” THEN scface.1.incorrect =
scface.1.incorrect + 1
       IF marker = 9 AND response.value$ = “d” THEN scface.2.correct =
scface.2.correct + 1
       IF marker = 9 AND response.value$ = “k” THEN scface.2.incorrect =
scface.2.incorrect + 1
       IF marker = 7 AND response.value$ = “d” THEN scface.3.correct =
scface.3.correct + 1
       IF marker = 7 AND response.value$ = “k” THEN scface.3.incorrect =
scface.3.incorrect + 1


INPUT #1, t$                            ‘get another line to process
WEND                                    ‘this is where the while loop ends
                              ‘++++++++++++++++++++++++++++++++++++++++++

PRINT #2, “subject”; sub.num
PRINT #2, INT(total.rt.FACE.1 / total.FACE.1); CHR$(9); (face.1.correct /
(face.1.correct + face.1.incorrect)) * 100
PRINT #2, INT(total.rt.FACE.2 / total.FACE.2); CHR$(9); (face.2.correct /
(face.2.correct + face.2.incorrect)) * 100
PRINT #2, INT(total.rt.FACE.3 / total.FACE.3); CHR$(9); (face.3.correct /
(face.3.correct + face.3.incorrect)) * 100
PRINT #2, INT(total.rt.FLOWER.1 / total.FLOWER.1); CHR$(9); (flower.1.correct /
(flower.1.correct + flower.1.incorrect)) * 100
PRINT #2, INT(total.rt.FLOWER.2 / total.FLOWER.2); CHR$(9); (flower.2.correct /
(flower.2.correct + flower.2.incorrect)) * 100
PRINT #2, INT(total.rt.FLOWER.3 / total.FLOWER.3); CHR$(9); (flower.3.correct /
(flower.3.correct + flower.3.incorrect)) * 100
PRINT #2, INT(total.rt.SCFACE.1 / total.SCFACE.1); CHR$(9); (scface.1.correct /
(scface.1.correct + scface.1.incorrect)) * 100
PRINT #2, INT(total.rt.SCFACE.2 / total.SCFACE.2); CHR$(9); (scface.2.correct /
(scface.2.correct + scface.2.incorrect)) * 100
PRINT #2, INT(total.rt.SCFACE.3 / total.SCFACE.3); CHR$(9); (scface.3.correct /
(scface.3.correct + scface.3.incorrect)) * 100

   CLOSE #1 ‘close the file being read from
   CLOSE #2 ‘close the distilled file being written
   PRINT sub.num; “ processed”

face1.tot = face1.tot + INT(total.rt.FACE.1 / total.FACE.1)
face1.cor = face1.cor + (face.1.correct / (face.1.correct + face.1.incorrect)) *
100
face2.tot = face2.tot + INT(total.rt.FACE.2 / total.FACE.2)
face2.cor = face2.cor + (face.2.correct / (face.2.correct + face.2.incorrect)) *
100
face3.tot = face3.tot + INT(total.rt.FACE.3 / total.FACE.3)
```

```
face3.cor = face3.cor + (face.3.correct / (face.3.correct + face.3.incorrect)) *
100
flower1.tot = flower1.tot + INT(total.rt.FLOWER.1 / total.FLOWER.1)
flower1.cor = flower1.cor + (flower.1.correct / (flower.1.correct +
flower.1.incorrect)) * 100
flower2.tot = flower2.tot + INT(total.rt.FLOWER.2 / total.FLOWER.2)
flower2.cor = flower2.cor + (flower.2.correct / (flower.2.correct +
flower.2.incorrect)) * 100
flower3.tot = flower3.tot + INT(total.rt.FLOWER.3 / total.FLOWER.3)
flower3.cor = flower3.cor + (flower.3.correct / (flower.3.correct +
flower.3.incorrect)) * 100
scface1.tot = scface1.tot + INT(total.rt.SCFACE.1 / total.SCFACE.1)
scface1.cor = scface1.cor + (scface.1.correct / (scface.1.correct +
scface.1.incorrect)) * 100
scface2.tot = scface2.tot + INT(total.rt.SCFACE.2 / total.SCFACE.2)
scface2.cor = scface2.cor + (scface.2.correct / (scface.2.correct +
scface.2.incorrect)) * 100
scface3.tot = scface3.tot + INT(total.rt.SCFACE.3 / total.SCFACE.3)
scface3.cor = scface3.cor + (scface.3.correct / (scface.3.correct +
scface.3.incorrect)) * 100

                                                 'reset values for next file
        total.rt.FACE.1 = 0: total.FACE.1 = 0: face.1.correct = 0:
face.1.incorrect = 0
        total.rt.FACE.2 = 0: total.FACE.2 = 0: face.2.correct = 0:
face.2.incorrect = 0
        total.rt.FACE.3 = 0: total.FACE.3 = 0: face.3.correct = 0:
face.3.incorrect = 0
        total.rt.FLOWER.1 = 0: total.FLOWER.1 = 0: flower.1.correct = 0:
flower.1.incorrect = 0
        total.rt.FLOWER.2 = 0: total.FLOWER.2 = 0: flower.2.correct = 0:
flower.2.incorrect = 0
        total.rt.FLOWER.3 = 0: total.FLOWER.3 = 0: flower.3.correct = 0:
flower.3.incorrect = 0
        total.rt.SCFACE.1 = 0: total.SCFACE.1 = 0: scface.1.correct = 0:
scface.1.incorrect = 0
        total.rt.SCFACE.2 = 0: total.SCFACE.2 = 0: scface.2.correct = 0:
scface.2.incorrect = 0
        total.rt.SCFACE.3 = 0: total.SCFACE.3 = 0: scface.3.correct = 0:
scface.3.incorrect = 0
NEXT sub.num
OPEN "totals.txt" FOR OUTPUT AS #1

PRINT #1, face1.tot / 12; CHR$(9); face1.cor / 12
PRINT #1, face2.tot / 12; CHR$(9); face2.cor / 12
PRINT #1, face3.tot / 12; CHR$(9); face3.cor / 12
PRINT #1, flower1.tot / 12; CHR$(9); flower1.cor / 12
PRINT #1, flower2.tot / 12; CHR$(9); flower2.cor / 12
PRINT #1, flower3.tot / 12; CHR$(9); flower3.cor / 12
PRINT #1, scface1.tot / 12; CHR$(9); scface1.cor / 12
PRINT #1, scface2.tot / 12; CHR$(9); scface2.cor / 12
PRINT #1, scface3.tot / 12; CHR$(9); scface3.cor / 12

CLOSE #1

END
```