The Effect of Audiovisual vs. Visual Startle Stimuli on Eliciting the Fear Response

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Abstract

Fear is an emotional response to various stimuli that many people will experience throughout different situations, some stimuli eliciting a larger response than others. This emotion can be accompanied by multiple physiological variations, such as in heart rate, sweat conduction, eye movement, and muscle contraction. This response can also be altered through the incorporation of multiple modalities of sensation. The purpose of our experiment was to investigate the fear response elicited by either visual or audio-visual stimulation, exploring the effects of these different stimuli on physiological variables. We compared these outcomes to determine if visual stimuli alone or audio-visual stimuli have greater effects on evoking the fear response and activating the sympathetic nervous system. 30 participants were randomly selected to be in either visual only, or audio-visual groups. The participants of the visual group were shown a 87 second clip with a 3 second interruption that contained a startle stimulus, but did not have a sound associated with it. The participants of the audio-visual group were shown the same video clip, except there was a sound associated with the startle stimulus. Since it has been shown that multiple stimuli evoke a greater physiological response than a single stimulus, it was hypothesized that the audio-visual group would have a greater physiological fear response to the startle stimulus than the visual group. Between both groups, those who were exposed to the audio-visual stimulus showed a significantly greater response in heart rate and eye movement, with muscle contraction and sweat conductance not showing significant results. However, there was an upward trend in sweat conductance, indicating bimodal integration of sensation has a greater effect than visual only. Overall, our study did not show significant results for all variables, but by measuring and comparing between the two groups, it was apparent that there are consistent physiological changes in responses between groups.

Introduction

Merriam-Webster dictionary defines fear as “an unpleasant, often strong emotion caused by anticipation or awareness of danger” (Merriam-Webster, 2017). Humans demonstrate a fear response not only to life and death situations, but also to many alternative stimuli that do not constitute a life threatening position. For example, horror films are created to elicit a fear response from the viewer, but without actually putting the viewer in immediate danger. An important aspect in evoking the full fear response in an individual is an incorporation of both audio and visual stimulation; this bimodality of sensations is shown to produce a stronger emotional reaction from each participant. (Collignon et al., 2008).

In one study it was found that emotions "are accompanied by physiological and behavioral changes that are an integral part of them", rather than just the single isolated feeling and accompanying mental state (Steimer, 2002). It is apparent that characteristic emotions will elicit precise, definitive physiological responses, and fear is no exception. Many of the physiological responses to stress involve sympathetic activation in the autonomic nervous system, which include the "fight or flight" response that prepares our body to protect itself from menacing stimuli. It all begins with the detection of alarming stimuli by our sensory organs, such as our eyes, ears, and nose. These organs then transmit a signal cascade to a small structure in the brain called the amygdala; it has been found that the amygdala plays a crucial role in the control of emotional behaviors. In one experiment, rats were exposed to electric shocks which were associated with a neutral cue (tone or visual signal). Soon after the pairing of the stimuli, the rats began to elicit a fear response to the cue alone (Davis, 1992). This shows that the amygdala is not only responsible for activating the fear response, but also in the cognitive processing of emotional information into long-term memory. This process, called fear conditioning, has been a focal point in further research regarding the amygdala (Davis, 1992).

Once the amygdala has been activated, it causes the sympathetic nervous system to be mobilized, thus stimulating the activity of the "flight or fight" system almost instantaneously. The release of norepinephrine and epinephrine onto beta-adrenergic receptors located on the SA node and ventricles of the heart causes an increase in both heart rate and contractility. The amygdala also inhibits the parasympathetic nervous system, which decreases the amount of acetylcholine released onto muscarinic receptors located on the SA node, thus inhibiting the "rest" effect of the parasympathetic system on heart rate (Widmaier et al., 2015). These effector

pathways occur almost immediately, with little time gap between the onset of the stimulus and effect of the autonomic nervous system. Activation of the sympathetic nervous system causes an increase in contraction of skeletal muscle to facilitate escape from a startle stimulus, which also occurs almost immediately after stimulus onset. Eye movement is controlled by the "lateral and medial rectus muscles, the superior and inferior rectus muscles, and the superior and inferior oblique muscles" (Purves, 1970). Thus sympathetic activation also causes an increase in contraction of eye muscles, resulting in increased eye movement when exposed to a startle stimulus. An increase in sweat conduction to startle stimulus is associated with sympathetic activation of the sweat glands (Bernstein, 2013). It has been shown that variation in sweat response is not necessarily associated with whether an individual thought the experience was pleasurable or not, but rather associated with the level of arousal the stimulus evoked within the individual (Bradley et al, 1990). This effect on sweat conductance is a more delayed response when compared to heart rate or muscle contractility; sweating is a mechanism to cool a person off, but in order to require this feature, skeletal muscle metabolism must first increase and burn more ATP to generate heat. This delay is then due to the increase in muscle metabolism that must first occur. Increasing heart rate, sweat conductance, and muscle contraction are a few of the outcomes that result from increased release of norepinephrine and epinephrine as a result of amygdala activation (Davis, 1992). All of these aspects work to increase our likelihood of escaping the threatening stimuli, thus enhancing our chances of survival. For example, an increased heart rate provides more blood flow to the skeletal muscles of the upper and lower extremities, adequately supplying them with oxygen and nutrients in case of emergency (Davis, 1992).

Although fear can induce a great deal of stress, many people still enjoy frequently watching horror movies. Films such as “The Exorcist” and “Saw” have brought in millions of dollars in gross profit despite their gory plots. What is it about these seemingly terrifying films that keeps people coming back for more? Important factors for determining frequency of viewing horror films varies between individuals; influential aspects include desire to experience conflict resolution at the end of the film, desire to witness destruction shown within the film, and sensation seeking personality traits of audience members (Tamborini, 1987). All of these factors can contribute to an increase in viewing frequency, which will lead to less sympathetic activation due to habituation. A decrease in sympathetic activation will lead to a smaller overall physiological response. Contrary to this mechanism, a person who does not watch horror films on a regular basis will not be habituated to this type of stimuli. In this case, they will still have a heightened physiological response due to normal sympathetic activation.

As we watch scary films we may understand that what we are viewing is not real, but despite this conscious awareness, it is thought that our brains will still react emotionally and fearfully to these films, almost to the degree as if they are real (Sparks, 1999). With this idea, it appears that as we watch horror films, our bodies react as if the dangers we are seeing are actually right in front of us. In response to this, our body elicits a fear response and subsequently, the physiological changes associated with it (DiFrancesco, 1993).

Although the visual images in horror films often can be sufficient enough to intrigue its audience, generally the audio connected with these images becomes an essential part in eliciting a full fear response in a person. In one study it was shown that “the perception of emotion expressions is a robust multisensory situation” (Collignon et al., 2008). Participants were first

asked to categorize fear expressions that were displayed either visually or audibly. This experiment showed that the participants were much better at categorizing the visual stimuli, which could suggest a visual sensory dominance. The participants were then asked to do the same thing, except this time the fear expressions were displayed visually and audibly together. Surprisingly, this experiment showed that the participants primarily categorized the fear expressions via the auditory modality, disclaiming the original prediction that there is visual sensory dominance. Further, they asked their participants to next try and focus on one sensory modality at time and ignore all of the rest. They found that even when the participants tried to focus solely on one sensory stimuli, the other senses seemed to still have an impact on what exactly they were processing from the stimuli. These results showed that there was a much better response when using multiple sensory modalities rather than a single modality (Collignon et al., 2008).

From these findings, we hypothesized that a participant's physiological response will be more profound when audio is connected to fear-inducing images. For example, a video clip with a sudden, frightening sound is expected to alert the sympathetic nervous system (increase heart rate, increase muscle contraction, rapid eye movement and increase sweat response) more than a video that does not have sound associated with the clip. This heightened physiological response of participants' that are shown a fear-inducing image with audio can most likely be attributed to the simultaneous stimulation of both the auditory and visual cortices.

Materials and Methods

This experiment consisted of 32 subjects (13 male, 19 female) from the University of Wisconsin-Madison Physiology 435 course. Subject age ranged from 20 to 23 years of age, with a mean age of 21.03. All subjects signed a consent form prior to the start of the experiment to inform them of any harm that could be caused to them and to ensure their confidentiality in completing the experiment.

Subjects were told that they would watch a video that would elicit an emotional response and that the basis of the experiment was how emotional reactions affected physiological response. The video was 87 seconds long and was custom created by our group to include a frightening interruption (FI) 42 seconds into the video. The video began with 42 seconds of various scenes of animals from the BBC Planet Earth series with sound followed by an interruption consisting of a 3 second video clip from Grave Encounters 2 (2012). For participants in the AV group (audiovisual) a loud, high pitched scream was added to the 3 second video clip. The frightening video clip was silenced for those placed in the VO (visual only) group. After the 3 second interruption, the video returned to scenes from the BBC Planet Earth series for an additional 42 seconds. The subject's heart rate (HR), finger sweat conduction (EDA), forearm muscle contraction (EMG), and horizontal/vertical eye movement (EOG) were recorded throughout the experiment.

To begin, a baseline was established using nine EL503 disposable electrodes (BIOPAC Systems, Inc. Goleta, CA), three SS2L leads (BIOPAC Systems, Inc. Goleta, CA), one pulse oximeter (Nonin Medical, Inc. Model 9843 Plymouth, MN), and one SS3LA lead (BIOPAC Systems, Inc. Goleta, CA) per subject. Six of the EL503 electrodes were attached around the

eyes while three more electrodes were placed on the left forearm. The pulse oximeter was clipped onto the right index finger. A small amount of Isotonic Recording Electro Gel 101 (BIOPAC Systems, Inc. Goleta, CA) was placed on the subject's left index and middle fingers followed by the SS3LA GSR leads.

Subjects were then randomly placed into one of two groups. Group 1 watched the video that had sound associated with the FI (audio-visual group, AV). Group 2 watched the same video, but lacked the sound associated with the FI (visual-only group, VO). A laptop and a pair of headphones (Sony) were given to the subject. Preliminary measurements were conducted until the subject showed a steady, relaxed state, about 30 seconds. Subject baseline data were measured as follows: heart rate (beats per minute), eye movement (mV), muscle contraction (mV), and sweat response (microsiemen). While the subject watched the video, these variables were monitored using BIOPAC Student Laboratory (BSL 4 software, MP36 hardware, BIOPAC Systems, Inc. Goleta, CA) and the pulse oximeter was monitored by videotaping the output with a cellular phone.

After the measurements were finished the subject was asked to complete a short survey to determine previous exposure to frightening stimuli and how they usually react to these stimuli (Figure 11). It also allowed them to record how scared they felt in response to the FI during the video, on a scale of 0-10 with 10 being a high level of fear, as well as frequency of watching frightening movies. Each participant was asked how often they watch scary films on a 0-5 scale with 0 being never, and 5 being often.

EMG data was analyzed by taking the average peak to peak, while EDA, EOG, and HR data were analyzed via averages. A data subset was analyzed over a 10s span during baseline, as

well as a 10s time frame encompassing the FI (42s to 52s into the video). EDA data was analyzed over a 20 second period following the FI (42-62 seconds in the video), due to a delayed response. Data gathered from both groups were averaged and compared to the average baseline of all participants in the study. Changes from baseline in HR, EDA, EOG, and EMG were recorded. A comparison was made between the groups based on the changes recorded. Survey data was also categorized and compared based on frequency of scary movie viewing, indicated fear level from the video, and the subject's susceptibility to being frightened.

In preliminary testing, we demonstrated that there is an observable change in all parameters. At the time of the FI, there was a discernable change from baseline, resulting in an increase of 20 bpm in HR, 0.3 mV EMG, 4 μS EDA, and 4 mV EOG. Our positive control is represented by Figure 12, taken during the 30 seconds of preliminary baseline. Our negative control data can be seen in the 42 seconds of video prior to the FI as no response was expected during this time period (Figure 2). Most of our variables hold constant without the onset of a stimulus; however, blinking of the eyes can be observed as short, sharp peaks within the EOG data. It is interesting to note that the EDA response and HR response take place after a short delay, while skeletal muscle-controlled movement (EMG) happens nearly immediately.

Results

The difference between baseline and peak values for heart rate (HR), eye movement (EOG), sweat response (EDA), and muscle contraction (EMG) were taken and compared across AV and VO groups. All physiological measurements display an increased fear response for the video that included sound with the FI as compared to the video that did not have sound

associated with the FI (Figure 6-9 and Table 1). Results are presented as mean plus/minus standard deviation and p-values were calculated using a one-way ANOVA test from VassarStats. Figures 2-5 include example fluctuations from the time period prior to the startle stimulus and during the startle stimulus in the video clip with sound.

The data for change in HR was calculated by subtracting the mean of the heart rate during baseline from the peak HR during the video clip interruption. The average change in HR was determined to be larger for the AV group than the VO group (Figure 6). For the AV group, the average increase in HR was 7.285 ± 6.28 beats per minute (bpm) from baseline. The average increase in HR for the VO group was 1.133 ± 5.221 bpm from baseline. The increased HR between the groups was found to be statistically significant ($p = 0.006$), which shows that there was a greater physiological response in HR to the startle stimulus in the AV group compared with the VO group.

The data for EDA was calculated by subtracting the average sweat conductance over the first 15-25 seconds of baseline from the average sweat conductance 42-62 seconds after the start of the video, during and immediately following the FI. An increase in sweat conductance of 1.192 ± 1.455 μS was observed among the AV group, while an increase in sweat conductance of 0.558 ± 1.384 μS was observed in the VO group from baseline values (Figure 7). When comparing the two groups, there seemed to be no statistical significance between the groups ($p = 0.239$).

Eye movement data was calculated by subtracting the average peak to peak value measured during baseline (15-25 seconds) from the average peak to peak value measured during the FI (42-52 seconds into the video) for each group. Eye movement was measured using two

channels (one to measure right eye movement and one to measure left eye movement), and the average eye movement from both of these channels were averaged together to come up with a total average eye movement for each participant in each group. The AV group showed an average change in eye movement of 0.834 ± 1.529 mV while the VO group showed an average change in eye movement of -0.0420 ± 0.231 mV from measured baseline values (Figure 8). The increased eye movement for the AV group was found to be statistically significant ($p= 0.017$), indicating that there was an increased physiological response in eye movement to the startle stimulus in the AV group compared to the VO group.

Muscle contraction data was calculated by subtracting the average peak to peak value during baseline (15-25 seconds) from the average peak to peak value during the FI (42-52 seconds in the video) for each VO and AV participant. For the AV group, the average change in muscle contraction was found to be 0.011 mV ± 0.032 mV, compared to an average change of -0.001 mV ± 0.003 mV in the VO group from baseline. When comparing these groups, it was determined that they were not significantly different ($p = 0.164$), although we found the average change in muscle contraction in the AV group to be greater than the average change in VO group (Figure 9).

Discussion

The change in all physiological responses measured can be attributed to the frightening clip (FI) that was inserted into the video. The larger deviation from participants in the AV group can be accredited to the body's sympathetic influence on heart rate, muscle contraction, eye movement, and electrodermal response. The sympathetic fight-or-flight response induces the

release of norepinephrine and epinephrine from the adrenal medulla which increases sinoatrial node activity in the heart, stimulates β-adrenergic receptors in skeletal and ocular muscles, as well as activation of sweat glands through sympathetic fibers located in the palms.

This experiment resulted in p-values that were shown not to be significant for EDA and EMG. However, when comparing data from AV and VO groups, there is some degree of consistency in the difference between the groups' responses. We suspect that a source of error for EMG measurements could have been arm placement during the experiment. Participants were instructed to rest their right arm in their lap as opposed to leaving it on the table. In future experiments, the placement of the arm should be reevaluated to ensure a minimized effect on muscle contraction. Regarding EDA measurements, possible sources of error can be attributed to inconsistency with the amount of conducting gel used for each participant, inconsistent cleaning techniques, and slight differences with the tightness that the EDA conductor was wrapped around the left index finger. These inconsistencies could be mitigated in future experiments by precisely measuring the same amount of conducting gel for each participant, ensuring that the EDA conductor was thoroughly cleaned and free of conducting gel after each participant, and tightly wrapping the EDA conductor around the left index finger to ensure accurate results from the participant.

This experiment supported our hypothesis that participants that had audio associated with the FI would exhibit a higher physiological response than participants that did not have audio associated with the FI. As shown in the results, heart rate, muscle contraction, sweat response and eye movement had a larger increase from baseline to peak for participants in the AV group over participants in the VO group. The survey indicated that participants in the AV group had an

overall higher level of fear than the VO participants, supporting the higher physiological responses that were shown in the experiment. Our survey allowed us to rule out potential bias due to desensitization to horror films, as our groups had no statistically significant difference in horror film viewing frequency.

For future experimentation, the study should include a video with no FI included as well as data to compare to the results from the AV and VO groups. Other aspects that could be changed include a longer duration of video prior to the FI, analyzing other emotions felt by participants in the post-experiment survey, and changing aspects of the video to be more calming scenes prior to the FI. Respiration rate could also be measured between the AV and VO groups. Comparisons between female and male responses in each respective group is also a component that could be added to future experimentation.

The results of this study shows that fear inducing clips paired with both audio and visual stimuli elicit a much larger physiological sympathetic response than visual stimuli alone. These findings could be useful in the production of horror films or other situations intending to produce a fear response, such as haunted houses. However, individuals creating these fearful films or situations would need to take these increased physiological responses into consideration for people whose health conditions may not be able to tolerate increased heart rate.

Figures and Tables

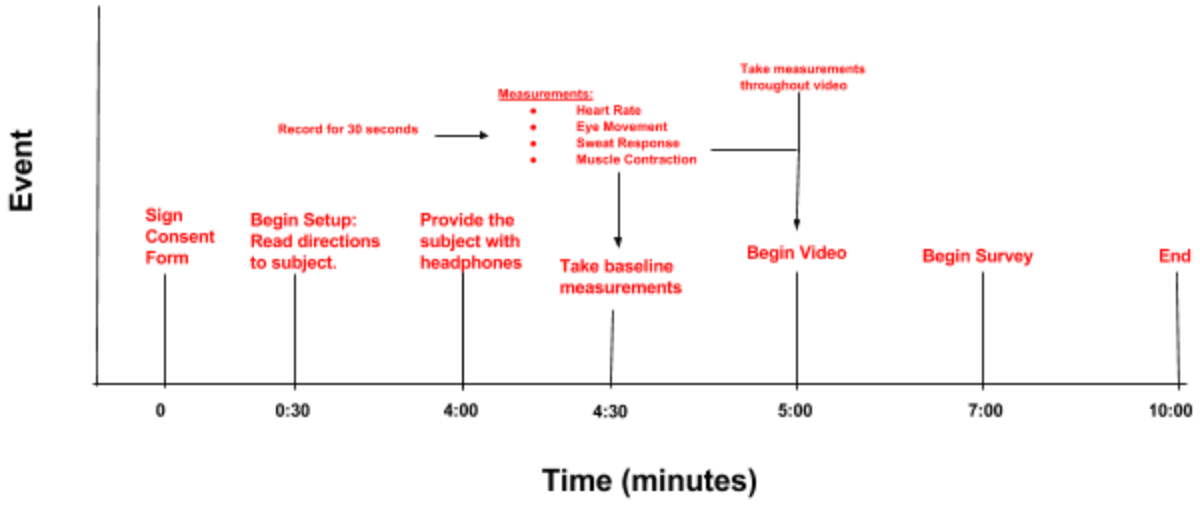

Figure 1. Timeline of events subjects will experience throughout the experiment. Note: these times are estimates and may vary based on the subject.

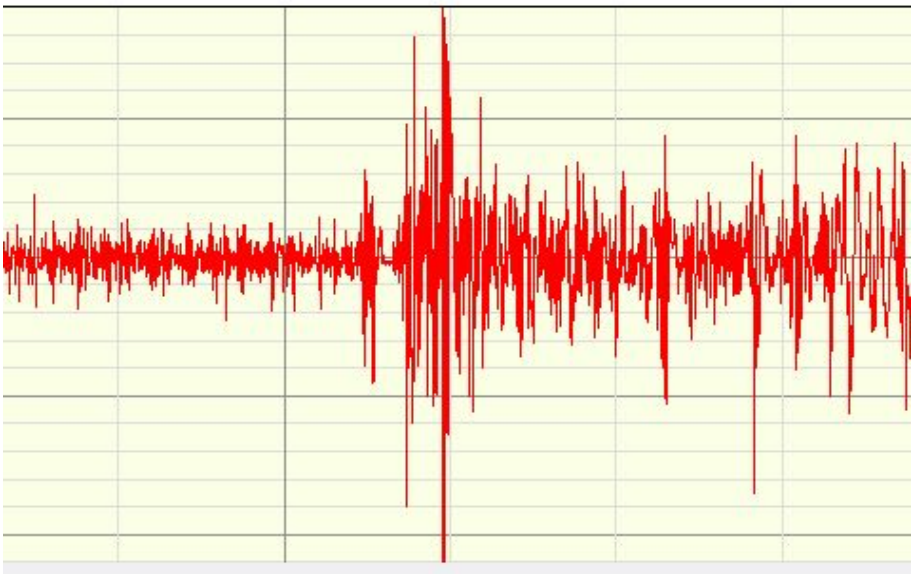

Figure 2. This figure shows an example of data from the BIOPAC EMG program. This participant was from the sound group. The beginning of the graph shows the participant's muscle contraction prior to the startle stimulus. As can be seen, there was little contraction during this time. The middle of graph shows the participant's response to the startle stimulus. The larger and more profound peaks indicate increased muscle contraction during the stimulus. Increased muscle contraction continued following completion of the stimulus. Y axis measured in mV and X axis measured in seconds. Time scale of 5 seconds from 40 seconds into the video to 45 seconds.

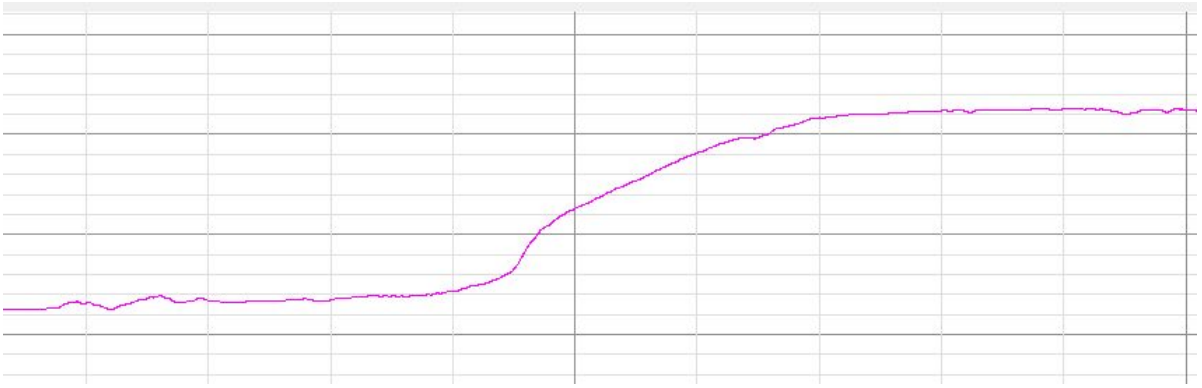

Figure 3. This figure shows an example of data from the BIOPAC EDA program. The left side of the graph shows the participant's sweat conduction prior to the startle stimuli. The middle of the graph shows the participant's sweat response to the startle stimuli. As can be seen, after the stimuli was shown the participant experienced an increased sweat conduction, but this response was delayed by a short time interval. This increased sweat response continued even after the video was complete.Y axis measured in mS and X axis measured in seconds. Time scale of 10 seconds from 40 seconds into the video to 50 seconds

Figure 4. This figure shows an example of data taken from the BIOPAC EOG program. The top graph shows movement of the right eye and the bottom graph shows movement of the left eye. Significant movement was taken to be large deviations from the normal, flat line. The left side of the graph shows eye movement before the startle stimulus. This is represented by relatively flat line and shows that there was little eye movement during this time. During and after the addition of the startle stimulus caused an increase in eye movement for both eyes, which is apparent from the large dips and waves in the graphs. The small dips seen throughout the graphs are likely due to the participant blinking throughout the video and were not considered to be significant

movement. Y axis measured in mV and X axis measured in seconds. Time scale of 5 seconds from 40 seconds into the video to 45 seconds

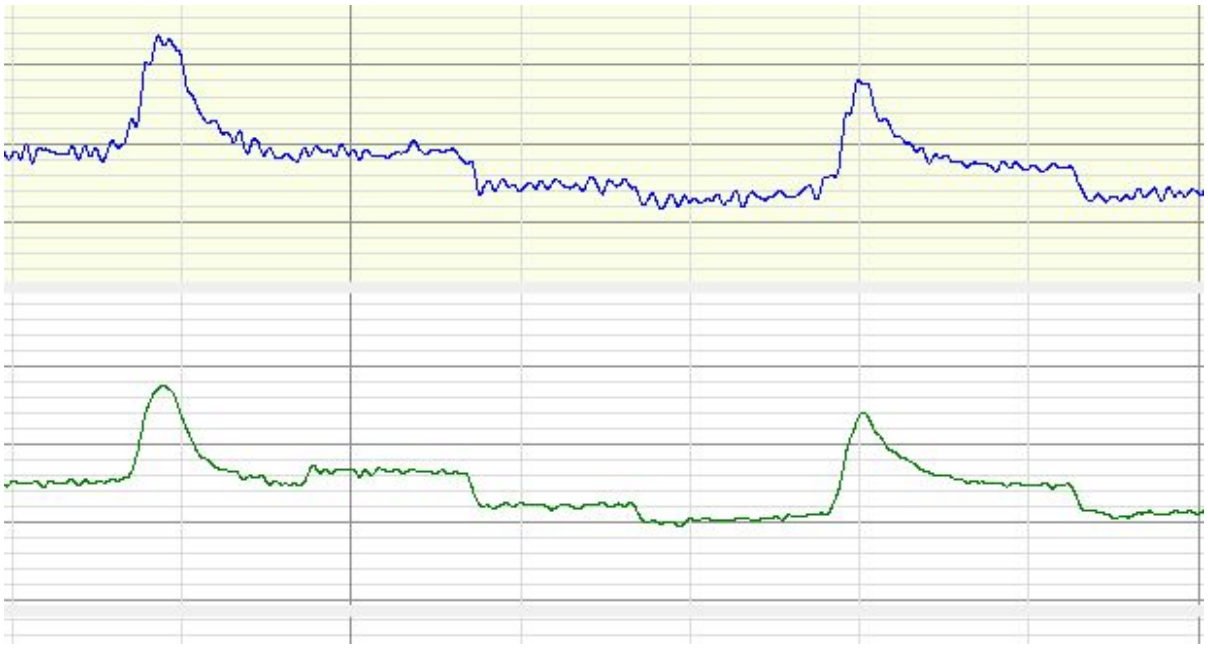

Figure 5. These graphs show an example of what blinks would look like in the BIOPAC EOG program. These peaks are generally sharper and have shorter wavelengths than other waves made by movement of the eyes. Y axis measured in mV and X axis measured in seconds. Time scale of 30 seconds from preliminary baseline measurements.

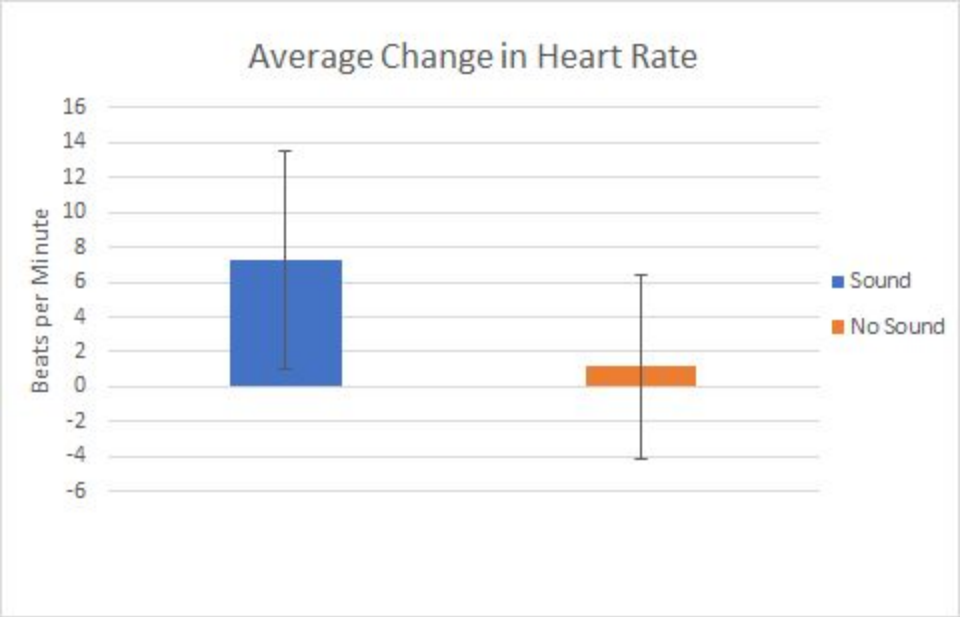

Figure 6. Participants in the audio-visual group had an increase in HR of 7.286 ± 6.281 bpm from baseline in response to the frightening stimulus. Participants from the visual-only group had an increase in HR of 1.133 ± 5.222 bpm. Error bars display standard deviation, p = 0.006.

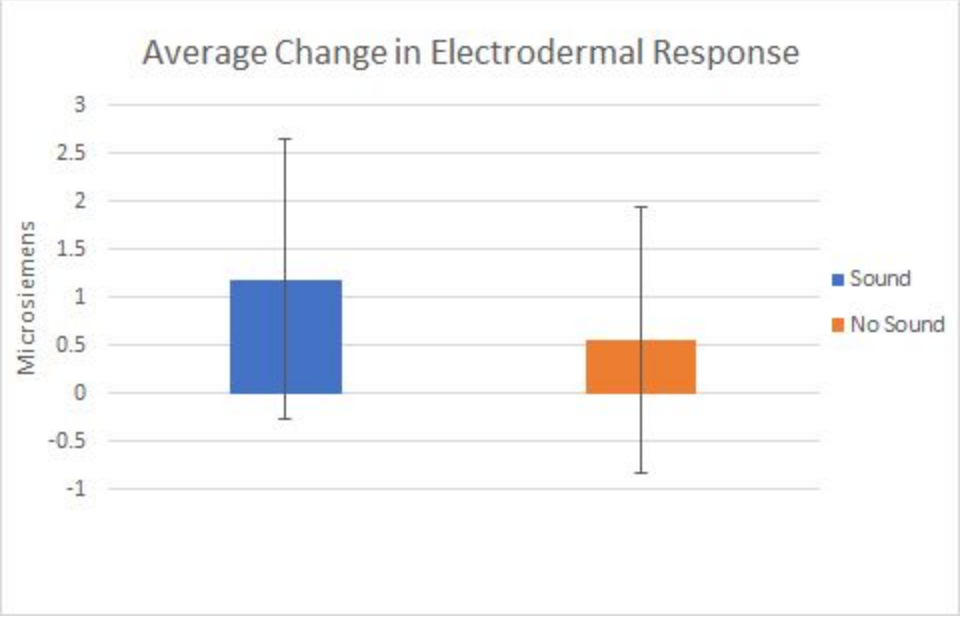

Figure 7. Participants in the audio-visual group had a 1.192 ± 1.455 μS increase in electrodermal response from baseline to peak during the frightening interruption. Participants in the visual-only group had a 0.558 ± 1.384 μS increase in electrodermal response from baseline to peak during the frightening interruption. Error bars display standard deviations, p = 0.239.

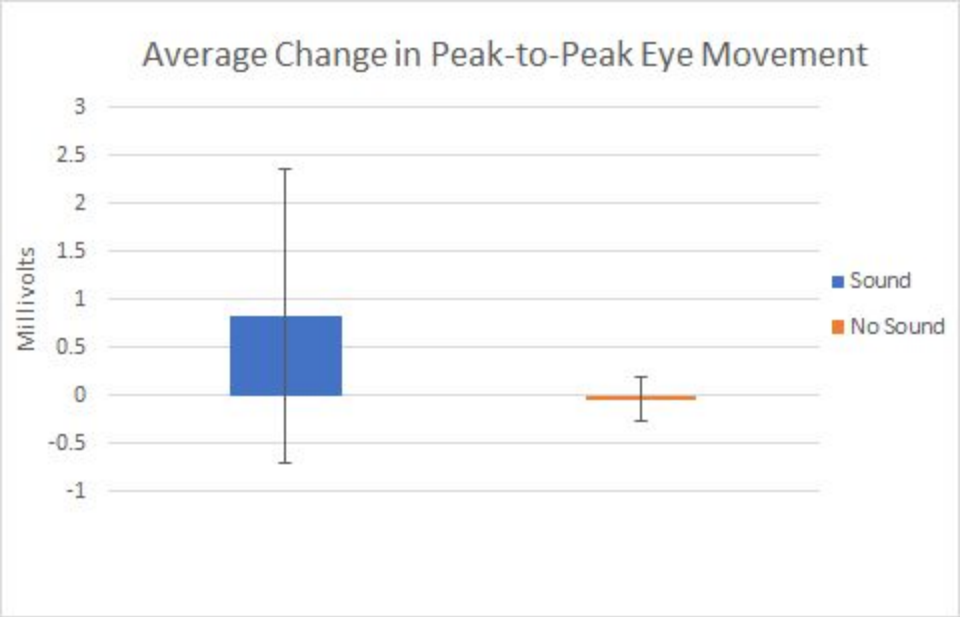

Figure 8. Participants in the audio-visual group had a 0.834 ± 1.529 mV increase in peak-to-peak eye movement from baseline to peak during the frightening interruption. Participants in the visual-only group had a -0.042 ± 0.231 mV increase in peak-to-peak eye movement from baseline to peak during the frightening interruption. Error bars display standard deviations, p = 0.017.

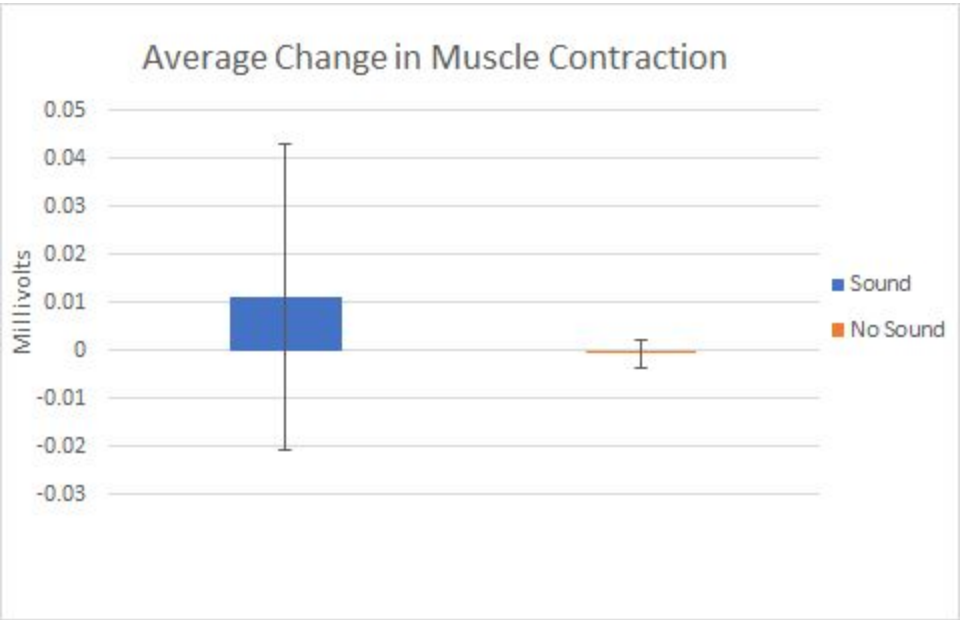

Figure 9. Participants in the audio-visual group had an increase of 0.011 ± 0.032 mV from baseline in muscle contraction due to the frightening stimulus. Those in the visual-only group had an average decrease in muscle contraction of 0.001 ± 0.003 mV. Error bars display standard deviation, p = 0.164.

Survey Results			
	Sound	No Sound	P-value
n (male, female)	16 (5, 11)	16 (8, 8)	Gender: 0.29
Age	21.4 ± 0.8	20.7 ± 0.6	0.01*
Level of fear (0-10)	5.1 ± 2.0	2.5 ± 1.5	0.0002*
Scary movie viewing frequency	1.3 ± 0.9	1.8 ± 1.2	0.19
Easily scared / frightened (Y/N)	0.69 ± 0.48	0.38 ± 0.50	0.08
Fun experience (Y/N)	0.81 ± 0.40	0.94 ± 0.25	0.30

Figure 10. Table shows survey results. Scary movie viewing frequency was based on the following scale: 0 = Never, 1 = Almost never, 2 = Seldom, 3 = Frequently, 4 = Often. For Yes/No responses: 0 = No, 1 = Yes.

Post-experiment Survey

What is your age? _____

What is your gender identity? _____

When the image flashed on the screen what was your level of fear? (circle one) 0= no fear, 10= terrified

0 1 2 3 4 5 6 7 8 9 10

How often do you watch scary films/clips? (circle one)

1) Often 2) Frequently 3) Seldom 4) Almost never 5)Never

Do you feel that you are easily scared/frightened?

1) Yes 2) No

Was this a fun experience?

1) Yes 2) No

Figure 11. This survey was given to each participant after the video clip in order to see if their age, gender, or previous exposure to startle stimuli had an effect on their physiological response to the startle stimuli in the video.

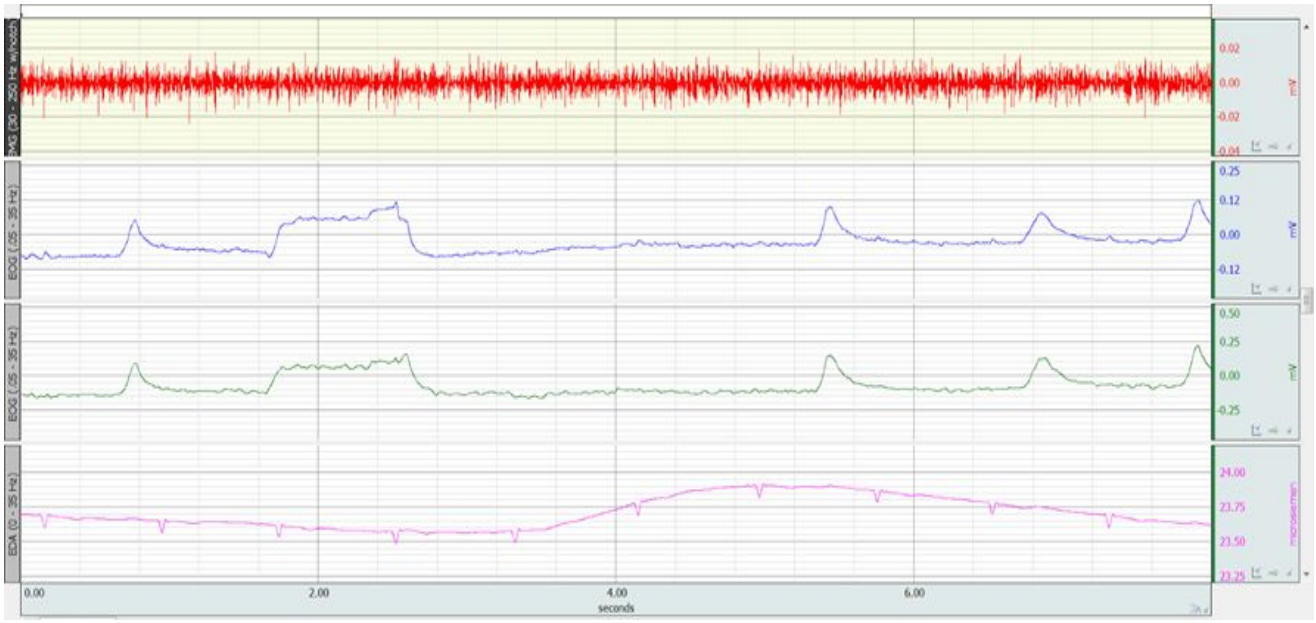

Figure 12: This figure is a representative example of positive control that was observed during the 30 seconds of baseline measurement that was taken for each participant. This baseline had a known response and was used to compare to the unknown response of each participant to the startle stimulus. Time scale of 7 seconds.

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