ELECTROENCEPHALOGRAPHIC MEASURES OF NEGATIVE PRIMING EFFECTS ON EVENT-RELATED POTENTIALS AND REACTION TIMES

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Abstract

Negative priming describes the effect in which reactions to a stimulus that has been previously ignored are slower and more error-prone. Reaction times and event-related potentials (ERPs) have shown negative priming for both visual and auditory stimuli. In the present study, two categories of auditory stimuli (musical instrument and animal sounds) will be presented in simultaneous pairs to assess whether categorically related stimuli produce negative priming effects differently from categorically unrelated stimuli. One stimulus in each pair serves as a target sound while the other is a distractor. Then, in a reversal condition, the distractor is presented as the target sound. The negative priming effect should be stronger for categorically related stimuli because similar sounds will be more closely associated in memory and therefore more difficult to distinguish from each other, resulting in longer reaction times and reduced ERP positivity in the negative priming condition. A revised study of ten participants investigated the effect of categories on positive priming effects. Reaction times showed a significant negative priming effect for stimuli from the same category.

Keywords: negative priming, reaction times, event-related potentials

Psychological research has explored many domains of functioning, such as cognition, sensation, and perception. A large body of research that connects all three psychological domains is the phenomenon of priming. Priming is a psychological process by which associations in memory are cued by stimuli just before a task is carried out. Extensive research on priming has established a consistent priming effect under the correct conditions. Priming causes objects that are similar to the primed stimulus to become more accessible and therefore easier to bring to mind. For example, a common way to assess the priming effect is to measure reaction times; priming usually causes the individual to react faster. When a stimulus, such as a dog bark, is experienced, it activates cognitive representations of related objects, such as other animal sounds, in memory, makes them easier to retrieve, and speeds up cognitive processing (Meyr & Buchner, 2006, Meyr et.al., 2006). This facilitation effect is manifested by shorter reaction times, suggesting faster cognitive processing. Studies also report fewer errors when responding to subsequent stimuli. Errors are typically measured by the number of incorrect responses made by a participant when responding to stimuli. For example, if participants are instructed to distinguish what type of animal sound is played in their right ear, an error would be defined as an incorrect determination. If the sound was a dog, and the participant responded with "frog," an error would be recorded (Mayr et.al., 2003).

Meyer and Schvaneveldt (1971) were the first researchers to discover the priming effect and as a result opened a completely new area of psychological research. Building on previous research conducted on the difference in reaction times between lexical, the grammatical formation of a word, and semantic, the meaning of a word, decision making, they studied the effect of meaning on lexical decisions. They investigated whether words

that had meaning made lexical decisions easier or more difficult (Meyer & Schvaneveldt, 1971). Their first experiment used twelve high school students as participants. These participants were shown two strings, or lines, of words at the same time and asked to determine if the words were all in English or not. The stimuli included 48 pairs of associated words, such as "nurse-doctor," or "bread-butter," 48 pairs of unassociated words such as "nurse-bread", or "butter-doctor," 48 pairs of non-words, such as "nulse-dofter," and 96 pairs of one word and one non-word, such as "nurse-dofter". The non-words were created by taking a word and changing one of its vowels or consonants (Meyer & Schvaneveldt, 1971).

The researchers found that participants responded significantly faster to the associated word pairs than the non-associated word pairs. Participants had faster reaction times when responding to words such as "bread-butter" than "bread-doctor." However, the rate of error between associated and non-associated word pairs was not significantly different, meaning the number of correct responses to both types of word pairs were the same on average. These results suggested that semantic associations between words facilitate lexical decisions and gave the first data that suggested a priming effect (Meyer & Schvaneveldt, 1971).

To further research the facilitative effect of word associations, Meyer and Schvaneveldt (1971) conducted a second study using twelve high school participants. The same stimuli were used as in the previous study with the addition of 16 more pairs of words and non-words, as well as 32 more pairs of words and non-words. The task was identical to the previous study, except that participants were instructed to respond based on whether the stimuli were the same (if the stimuli were two words or two non-words),

or if the stimuli were different (a word paired with a non-word) (Meyer & Schvaneveldt, 1971).

The results of the second experiment showed that participants responded significantly faster to stimuli that were the same than to stimuli that were different. Responses were also significantly faster for paired stimuli that were associated with each other than for stimuli that were not associated. Participants made significantly fewer errors when responding to associated stimuli than when responding to unassociated stimuli. These results were consistent with the previous study in giving evidence for the facilitative effect of association (Meyer & Schvaneveldt, 1971).

The implications of Meyer and Schvaneveldt's (1971) studies were of great importance. The shorter reaction times for associated stimuli suggested a theory of memory storage in which memories are stored semantically, meaning when a word is activated, other related words are also activated. This means that, when a decision about one word is dependent on a decision about a second word, the time it takes to respond depends on how the words are linked in memory. When the words are associated, they have similar characteristics that link them together. When one of the words is retrieved from memory, the associated words are activated, decreasing the amount of time it takes to recall them. When the words are unrelated, they are not linked and therefore not activated together, resulting in longer reaction times. The closer association of the two related words allows one to access information about the second word faster than if the second word is unrelated and not associated in memory.

This leads to the idea that there is a spreading activation in the brain, and that when a word is retrieved, all the content in closely related categories and locations are

activated and set in a state of excitation, preparing them for later retrieval, thereby making it faster and easier. Memory is stored in a series of nodes that are connected by pathways that are formed between concepts that are related or associated. When a memory is recalled it is activated, and the activation subsequently spreads through these networks and partially activates related memories. This facilitates later processing of those memories because the partial activation readies them for recall. This is a forward-acting process in that activation starts when the prime is perceived, and spreads forwards into the probe analysis. These theories combined together led to the discovery of the priming effect, a theory later supported by an abundance of research studies that confirmed the effect (Meyer & Schvaneveldt, 1971; Tipper, 2001).

Since Meyer and Schvaneveldt's (1971) experiment, priming research has expanded into various other aspects of its effects. Herr, Sherman, and Fazio (1982) studied the assimilation and contrast effects of priming. Assimilation effects are seen when exposure to a stimulus causes a person to respond to other stimuli in the same direction as they responded to the original stimulus. Contrast effects are seen when exposure to a stimulus causes a person to respond in the opposite direction than their original response. They specifically studied how priming will affect the later categorization of ambiguous stimuli. They proposed that the differential categorization of an ambiguous stimulus depends on both how accessible a category is and how recently the category was last activated. Accessibility refers to how easily a concept or idea can be retrieved from memory. Accessible categories are easily recalled and remembered, while inaccessible categories are more difficult and take more cognitive effort to recall. Usually, the more recently a category or stimulus was activated or recalled, the more

accessible it is. Therefore, if a category was recently activated by a prime, it is more easily used to characterize or encode a later stimulus. Encoding refers to the act of storing objects in memory that allows later retrieval of the object by transforming an aspect of a visual, semantic, or acoustic stimulus into a cognitive representation in memory that can be consciously retrieved. Priming makes it easier for encoding to occur because it is easier to store information in already activated categories. Priming is therefore a positive automatic process in which the more accessible a category is, the more likely a stimulus will be encoded in that category.

Herr et.al. (1982) also proposed that priming can either cause assimilation or a contrast effect. The assimilation effect is seen when a primed category causes later judgments to be made in the direction of that category, while the contrast effect occurs when a primed category causes later judgments to be made in the opposite direction of the category. They hypothesized that, for judged stimuli, ambiguity would create assimilation effects and unambiguity would cause contrast effects.

Herr et.al. (1982) further proposed that the extremity of the primed category would affect judgments, and that extreme primed categories would show contrast effects. Essentially, the researchers predicted that while priming usually influences one's reactions in the direction of the primed stimulus, when the prime is too blatant, the effect will be reversed and a person will react in the opposite direction of the prime. The prime will be used as context against which the person will judge the probe (Herr et.al., 1982). For example, Sherman, Ahlm, Berman, and Lynn (1978) found that when asked to rate the importance of recycling, participants rated it significantly less important when also asked about serious social issues such as abortion laws, but they rated it significantly

more important when asked about relatively inconsequential issues such as laws requiring lids on trashcans. Giving a context against which to judgments can be made affects the perceived degree of extremity of the probe (Herr et.al., 1982).

The experiment consisted of 80 subjects across four conditions. Participants were shown ten pairs of slides and instructed to memorize the first word on the first slide of each pair. These memory words included four animal names. The animals were rated on a scale of ferocity (e.g. “shark” being high ferocity, “kitten” being low ferocity). The second slide consisted of one of four colors and another word. The word on the second slide would directly contrast with the color, such as a green color slide with the word “blue,” interfering with the participant’s ability to read “blue” when looking at the color green. Response times were recorded. Then participants were instructed to look at pictures of animals and rate the animal’s ferocity. The ambiguity of the animals was measured by whether the animal presented was real or unreal. Unreal animals were made-up by the researchers. Results showed that moderately extreme primes produced assimilation effects when paired with ambiguous stimuli. However, when judging unambiguous stimuli, contrast effects occurred because participants judged the stimuli against the prime (Herr et.al., 1982).

To expand on their study, Herr et.al. (1982) conducted a second experiment in which they replaced participants’ ratings of ferocity with ratings of size, since it is a less ambiguous dimension. The participants were 56 undergraduate students. They were given a list of 60 animals and instructed to rate them based on size (e.g. “whale” is extremely large, “snail” is extremely small). With the exception of using size instead of ferocity, the method was identical to Herr et.al.’s (1982) first experiment. Participants

rated not only the size but also the length and the weight of the animal. The moderately sized animals acted as the ambiguous stimuli, while the extreme sized animals acted as the unambiguous stimuli. Results showed that participants rated real animals larger than unreal. They also found that when priming extreme animals, or unambiguous stimuli, a contrast effect occurred, while priming moderate animals caused an assimilation effect to occur (Herr et.al., 1982).

The results of Herr et.al.'s (1982) experiment provides support and more evidence for the wide reaching effects of priming. Not only does priming facilitate responses and decrease reaction times, it also influences what type of reactions will occur. This provides evidence for the hypothesis that priming activates a location in the brain around which activation spreads, preparing related areas and categories to respond. Higgins and King (1981) call this theory the energy cell process, which is a cell activation model that suggests the activation of cells stimulates the activation or excitation of other surrounding cells. Another theory Herr et.al.'s (1982) experiment gives evidence for is a storage bin model, in which primed categories are easier to access because they were recently activated, similar to Meyer and Schvaneveldt's (1971) location model. The results of these experiments also suggest that the extremity and ambiguity of primed categories affect the direction in which participants respond (Herr et.al., 1982).

While most of the early priming research focused on positive priming, in which the prime speeds up processing when the subject experiences the priming stimulus and responds, negative priming occurs when one must attend to a previously ignored stimulus. For example, the first study on the negative priming effect was conducted by Steven Tipper in 1985. In his first experiment, the effect of ignoring prime stimuli and

naming identical probe stimuli was investigated. To determine the effect of first ignoring a stimulus and then attending to it, the latency in reaction times was measured. Recall was also measured. Twenty-four participants were shown a green drawing that had a red drawing superimposed over it. They were to ignore the green drawing while identifying the red drawing. The red prime drawing had a darker outline than the green probe drawing in order to direct attention to the correct image.

Participants were divided into two conditions. The experimental condition had identical prime and probe drawings, while in the control condition the primes and probes were unrelated. In the second presentation of the prime and probe stimuli, the red drawings were superimposed on random green lines and participants had to identify what the red drawings were. The red target drawings in the second presentation were identical to the ignored green probe drawings in the first presentation (Tipper 1985).

Results showed that in the experimental condition, when participants had to identify a previously ignored stimulus, the average reaction time was 797 milliseconds, while the average reaction time for the control condition, when participants merely had to identify unrelated stimuli, the average reaction time was 749 milliseconds, indicating a significant difference between the conditions and giving evidence of a negative priming effect. It suggested an inhibitory effect when one must attend to a previously ignored prime (Tipper 1985).

Tipper (1985) conducted a second experiment to further support and expand on the negative priming effects found in his first study. The method was identical to the previous experiment except that the probe drawings in the control condition were changed to be meaningless parts of the ignored prime in order to test the sensitivity of the

negative priming effect on ignored stimuli. The inter-stimulus interval between the prime and probe presentations was also changed from 1,000 to 300 milliseconds, in order to determine if time has an effect on negative priming. The results of this second experiment again showed a significant increase in reaction time for the negative priming condition. The average reaction time for the experimental condition was 909 milliseconds, compared to 865 milliseconds for the control condition, increasing the support for the negative priming effect. Reaction times were also significantly longer compared to the first experiment due to the decreased inter-stimulus interval between the prime and probe trials.

A third experiment was conducted by Tipper (1985) to build on the negative priming effect. This study looked at how reaction times during negative priming would be affected by categorically related primes and probes. Tipper used additional conditions for this experiment. The conditions included the ignored and selected prime being the same as the probe, the ignored and selected prime being unrelated to the probe, the ignored prime being identical to the probe, and the ignored and selected prime being semantically related to the probe. The procedure was the same as the previous two experiments. Results showed that it took an average of 31 milliseconds longer to respond to a probe that was semantically related to an ignored prime than when the probe was unrelated to the ignored prime. This suggests that there is a spreading inhibition of semantic networks (Tipper 1985). When a stimulus is primed, spreading activation excited related networks in the brain, as shown in Meyer and Schvaneveldt's (1971) as well as Herr et.al.'s (1982) experiments. However, when a primed stimulus is ignored, there is the opposite result of a spreading inhibition of related concepts, causing it to take

longer to react to stimuli categorically related to a previously ignored stimulus (Tipper 1985).

Since Tipper's (1985) highly successful experiments, several studies have examined various aspects of the negative priming effect. Banks, Roberts, and Ciranni (1995) extended negative priming into the auditory domain. When presented with a prime target sound in one ear at the same time as a prime distractor in the other ear, and then later presented with the distractor as the probe target, a negative priming effect occurs. However, this effect only lasts for one probe presentation after the prime. Subsequent presentations showed no evidence of a negative priming effect (Banks et.al., 1995). Yee, Santoro, Grey, and Woog (2000) studied the effects of negative priming on the conceptual, rather than physical, properties of stimuli. Their hypothesis was that deeper levels of processing would create larger negative priming effects. Deep levels of processing could be generated by focusing on perceptual, rather than conceptual, characteristics of stimuli. Yee et.al. (2000) used color as a perceptual target and size as a conceptual target. They found a larger negative priming effect occurred during deeper processing, evidenced by longer reaction times for color than size targets, as the prime distractor was extensively processed for conceptual stimuli. Enough information about the distractor must be processed in order to make the decision to ignore or respond to it, resulting in deeper processing when more information is necessary to make the decision (Yee et.al., 2000).

These experiments provide evidence for Tipper's (1985) theory of spreading inhibition, in which when a stimulus is ignored, the accessibility of it is inhibited. When the subject then needs to activate the stimulus, the brain must overcome the inhibition,

causing a decrease in the speed of processing. However, a second theory of episodic retrieval has been proposed that suggests when a stimulus is negatively primed, the brain learns to inhibit the response. When a response is then required, a conflict occurs and must be resolved, resulting in slower processing (Mayr & Buchner, 2006).

Episodic retrieval theory proposes the idea that when stimuli are encountered they are stored individually in memory. A stimulus, as well as its context and required response when first encountered, are encoded together as an episode. When later retrieval of the stimulus is necessary the whole episode is activated. This is an automatic process, meaning it is an action that is unconsciously performed. Unlike distractor inhibition, it is a backward retrieval process in that, when the probe is perceived, the prime stimulus that was encountered in the past is processed. This is normally facilitative in that it allows more rapid and less effortful responding. During negative priming, however, it interferes with responding. In the prime trial, the prime distractor becomes encoded with a nonresponse requirement. On its next presentation as the probe target, this encoded nonresponse is contradictory to the task, which now demands a response. Therefore, the nonresponse requirement that was originally encoded with the stimulus must be overcome, a time consuming and effortful action, resulting in the slower reaction times that are seen in negative priming (Neill, Valdes, Terry, & Gorfein, 1992).

Evidence for the episodic theory of negative priming is given by the study conducted by Meyr and Buchner (2006). This study used auditory rather than visual stimuli, as the researchers were trying to give evidence for episodic retrieval in the auditory domain. Eight-six participants were presented with two categories of sounds, either instrument or animal.

A pre-prime pair of sounds was played, followed by a prime pair, and then a probe pair. Each pair played one sound in each ear. Participants had to ignore one sound, the prime distractor, while attending to the other simultaneous sound, the prime target, and decide whether the target sound was an instrument or animal. In the negative priming condition the distractor in the prime trial was later attended to in the probe trial. For example, in the prime trial a participant would attend to a duck in their left ear, while ignoring a lamb in their right ear. According to the episodic retrieval theory, this should cause the lamb to become encoded with a do-not-respond tag and the duck should be encoded with the actual response (Meyr & Buchner, 2006).

In the following probe trial, the participant would attend to the lamb in their right ear, while ignoring the sound playing in their left ear. Retrieving the lamb from memory and responding to it should cause a negative priming effect because one must overcome the do-not-respond tag that was previously created when it was originally encountered in the prime trial. The control condition did not repeat sounds, but had all the sounds in the prime and probe trials differ. For example, the prime trial would include a target sound of a duck in their left ear at the same time as a distractor sound of a lamb in their right ear. The probe trial would include a distractor sound of a frog in their left ear and a target sound of a piano in their right ear. This non-repetition of sounds is important because it ensures that there will be no negative priming effect due to the novelty of each stimulus during each presentation. The interval between the pre-prime, prime, and probe trials also varied, being either 500 or 5,000 milliseconds, to determine the effect of time on negative priming (Mayr & Buchner, 2006).

Results showed a negative priming effect in that reaction times in the negative priming condition were significantly longer than those in the control condition. Reaction times were also significantly longer when the inter-stimulus interval was 500 milliseconds compared to 5,000 milliseconds, suggesting the negative priming effect is stronger when stimuli are presented closer together and decreases in strength as time progresses. Results also showed that reaction times were longer when the pre-prime interval was 500 milliseconds, and shorter when the interval was 5,000 milliseconds. This means that when the prime is located temporally close to the preprime the likelihood that the prime and pre-prime episodes will get confused upon retrieval increases. Separating the information to retrieve the correct response is what causes the increased reaction times in shorter pre-prime-prime intervals (Mayr & Buchner, 2006).

The results of this experiment give strong evidence for the episodic retrieval theory of negative priming. The distractor inhibition model cannot explain the results because, if spreading inhibition after ignoring a sound accounted for the negative priming effect, the duration of the pre-prime interval would not make a difference in the strength of inhibition because the interval occurs before the prime inhibition takes place. However, there was a significant increase in reaction times when the pre-prime interval was shorter. The episodic retrieval theory can account for these results because the pre-prime trial increases the probability that the prime episode will be retrieved. This then determines the probability that the information from the prime stimuli will interfere with the participant's response to the target in the probe trial. Essentially, the pre-prime trial readies the brain to respond to the prime trial, while at the same time causing the brain to not respond to any other stimuli. When the probe trial is presented, the prime stimulus

interferes and the brain must then overcome its previous instructions to not respond to the probe stimuli (Mayr & Buchner, 2006).

To further investigate these two theories, Mayr, Nieggeden, Buchner, and Orgs (2006) used physiological variables to examine the negative priming effect. They specifically explored how negative priming changes event-related potentials and reaction times in the anterior, medial, and posterior regions of the brain. Earlier research has shown that negative priming causes a delay in reacting to the stimulus after it was ignored in its first presentation. Research has also shown that there is a change in event related potential in the negatively primed situation. To measure such changes more precisely, Mayr et. al. used event-related potentials (ERP) (Mayr et.al., 2006).

ERP is the measure of brain activity during a cognitive task. When an event or stimulus is encountered the brain emits small electrical signals that reflect the amount of postsynaptic potential in the brain, by which one can measure the amount of activity in the brain. ERP is measured through electroencephalography (EEG) by placing electrodes on the scalp in areas that correspond to specific regions of the brain. The EEG measures the electrical impulses of ERPs. There are two types of waveforms that the EEG measures: sensory ERPs, which occur directly after the stimulus and indicate the direct experiencing of the stimulus, and cognitive ERPs, which follow after the first waves and denote information processing. ERP waves are measured by amplitude and latency, the amount of delay after the stimulus presentation (Sur & Sinha, 2009).

Thirty participants were studied in this experiment. The stimuli included six sounds, three of which were animals (frog, bird, and hen) and three of which were musical instruments (piano, guitar, and cornet). In the negative priming trials two sounds

were presented simultaneously, one in each ear. Then, two more sounds were presented in the same fashion. A click would indicate which ear the participant should attend to and then categorize the sound as an animal or musical instrument. For example, a frog would play in the left ear and a bird in the right ear for the prime trial. If the click played in the left ear, the participant would categorize the frog. On the next stimulus presentation, the probe trial, a hen would play in the left ear and the bird would play in the right ear again. The click would play in the right ear, causing the participant to attend to the previously ignored sound, creating a negative priming effect. The control trials consisted of two pairs of sounds presented in the same way, but all four of the sounds differed. For example, a dog would play in the left ear while a hen would play in the right for the prime trial, and then in the probe trial, a bird would play in the left ear while a piano would play in the right ear. The click was still used to indicate which ear the participant was to attend (Mayr et.al., 2006).

The results of this study measured ERPs, reaction times, and error rates. The average reaction times in the negative priming condition were significantly longer than for the control condition, with an average difference of 29 milliseconds. There were also significantly more errors in the negative priming trials than the control trials. The average error rate for the negative priming trials was 5.37% while the error rate for the control trials was only 3.36%. This suggests that negative priming not only causes slower reaction times, but increases the risk of error (Mayr et.al., 2006).

Mayr et. al. (2006) also found that the slowing of cognitive processing produced by negative priming appeared as decreased ERP positivity. To measure the ERPs, results were separated into anterior, posterior, and medial electrode clusters because the

arrangement of the electrical signals suggested that the majority of the effects appeared in those clusters. In analyzing the ERP data, the researchers predicted that the negative priming effect would be shown by a decreased ERP positivity in the posterior leads 300 to 600 milliseconds after the probe stimulus presentation. However, the difference in ERP negativity between the negative priming and control trials was not significant, although it was close and replicated previous studies in a smaller degree (Mayr et.al., 2006).

The ERP results were also separated into slow and fast responses, each analyzed separately. Negative priming effects in the posterior, medial, and anterior electrode clusters were not significant. In spite of this, a negative priming effect could be visually observed in the waveform. There was a significant difference in the mean amplitudes of the anterior electrode clusters in that negative priming trials showed a more positive amplitude, showing greater processing (Mayr et.al., 2006).

There was also a typical negative priming effect for fast and slow reactions, but a larger effect for slow reactions, suggesting a correlation between longer reaction times and stronger negative priming effects. There was stronger evidence for this effect in reaction time data than in ERP analysis. The finding that longer reaction times are associated with larger negative priming effects has multiple implications. It supports the distractor inhibition theory in that the cognitive representation of the ignored prime must be suppressed to allow one to process the target stimulus. Longer response times allow inhibition to develop more completely as it gets stronger over time, causing a longer delay in responding when well-developed inhibition must be overcome in the probe trial. Short response times overcome an incomplete inhibition, when not all of the task-

irrelevant neural networks are inhibited. When the response time increases, it allows for a more complete inhibition of the irrelevant neural networks. When these networks must then be responded to, it is more difficult as the inhibition is more complete (Mayr et.al., 2006).

The episodic retrieval theory could also account for these findings. According to this theory, the negative priming effect can be attributed to a conflict when a stimulus tagged with "do not respond" later requires a response, causing a delay in reacting. Longer reaction times have a larger change of a negative priming effect because it allows the brain to fully process data, resulting in more successful prime retrievals, while fast responses are already prepared before the stimulus presentation and therefore do not affect processing of the next stimulus. Essentially this means that negative priming makes additional processing necessary, thus slowing the reaction (Mayr et.al., 2006).

The logic of negative priming extends to a large body of research on the Stroop effect. In a Stroop task, participants are presented with the name of a color, such as "yellow", written in a different color ink, such as blue. Negative priming is used when the participants are told to name the color of the ink, while ignoring the actual word. This required the subject to ignore the spelled word and only attend to the color of the ink. Thus, participants must inhibit responding to the meaning of the color words and respond to the color of the ink. The presence of the color name is thus a negative prime. Researchers have consistently found that reaction times in this negatively-primed condition were significantly slower than in the control condition, in which the word and color ink were the same (for example, the word "yellow" was written in yellow ink).

Participants also make more errors in the negatively-primed condition (Dalrymple-Alford & Budayr,1966).

Marí-Beffa, Estévez,and Danzinger (2000) conducted a study that combined negative priming and the Stroop task. Earlier research on the Stroop task found that when subjects were required to report only a letter instead of a whole word, the effect was eliminated, suggesting that the whole word was not processed. Marí-Beffa et.al. (2000) combined negative priming with the Stroop task to determine if this conclusion was correct or if there was a different explanation for the lack of effect when participants reported only one letter during the task.

The stimuli used in this experiment consisted of four Spanish color words (rojo, azul, verde, blanco), which were classified as incongruent stimuli, and four related non-words (ronu, azej, velti, blasde) which were classified as neutral stimuli. In the first condition, the all-letter-colored condition, the words were presented in either red, blue, green, or white, while in the second condition, the single-letter-colored condition, only one letter of each word was colored. The color used in either condition was always different than the color the word spelled, and different than the color to which the non-word had the closest spelling (Marí-Beffa et.al., 2000).

Participants were presented a prime stimulus followed by a probe stimulus and were instructed to identify the color of the word or letter by pressing a response key. The prime trials consisted of both words and non-words and both color conditions while the probe trials consisted of only the all-letter-colored condition. The prime and probe pairs could either be related, having the color of the probe word be the same as the meaning of

the prime word, or unrelated, having the color of the probe word be different as the meaning of the prime word (Marí-Beffa et.al., 2000).

In the prime trials participants reacted faster to the all-letter-colored condition than the single-letter-colored condition, with average reaction times being 752 milliseconds and 804 milliseconds, respectively. There was no significant difference between color conditions for the probe trials but there was a significant effect of relatedness. Reaction times were significantly slower for related trials in which the average reaction time was 790 milliseconds than unrelated trials, in which the average reaction time was 774 milliseconds. Most importantly, there was a significant negative priming effect when the prime was a word and a non-significant effect for non-word primes (Marí-Beffa et.al., 2000).

Marí-Beffa et.al.'s (2000) study shows that there is a negative priming effect following a prime word for both words that are completely colored or only have one letter colored. There was no effect for non-word primes, suggesting that prime words were in fact being processed, contrary to previous hypotheses. This means that, although there was no Stroop effect, one cannot come to the conclusion that the words were not processed. If the words were not processed there would be no evidence of a negative priming effect for the single-letter-colored condition, but this was not the case. This experiment gives evidence that both words and non-words created the same amount of cognitive interference when trying to name the color of the word while ignoring the meaning of the word. However, it is just as likely that neither condition created interference due to the existence of negative priming in the probe trial. This is important because when comparing effects across two conditions, it is impossible to tell if the

interference effect, or lack thereof, is dependent on one or both conditions (Marí-Beffa et.al., 2000).

To determine if the lack of a Stroop effect was due to the incongruent or non-word conditions, Marí-Beffa et.al. (2000) conducted a second experiment that used the same method as the original study with the exception of an additional condition. A neutral condition was added that comprised a row of Xs that was the same length as the original words and non-words. Xs were used as stimuli that would create a minimal amount of interference, allowing a distinction to be made between the incongruent and non-words in order to determine which condition was creating the interference and causing a delay in reaction times. When used in the prime trial, a row of Xs would be either the same length as the probe color word or non-word, making them related stimuli, or a different length, making them unrelated (Marí-Beffa et.al., 2000).

Similar to the original study, results showed significantly faster reaction times in the prime trials for the all-letters-colored condition, with an average response time of 761 milliseconds, than the single-letter-colored condition, showing an average response time of 807 milliseconds. Participants also had significantly faster reaction times for the string of Xs condition, 770 milliseconds, than both the word and non-word conditions. This suggests that interference was created in both the word and non-word conditions, as the response times did not significantly differ from each other. In the probe trials there was again a significant negative priming effect. The effect was larger for related prime and probe trials when compared to unrelated trials. However, the negative priming effect for words was significantly greater than for non-words and the string of Xs condition (Marí-Beffa et. al., 2000).

The results of Marí-Beffa et.al.'s (2000) study is notable in that it shows there is different processing between incongruent words and non-words due to the appearance of a negative priming effect for the former but not the latter. Therefore, one cannot assume that an absence of the Stroop effect means there was not a complete processing of the word. It also shows that the Stroop task, while it can confirm the presence of negative priming, cannot determine the cause of negative priming effects (Marí-Beffa et.al., 2000).

Episodic retrieval could account for the effect, but seems unlikely due to the fact that negative priming did not increase in correlation with an increase in the relatedness of the prime and probe trials. Episodic retrieval would have been shown by a positive correlation between relatedness of stimuli and the negative priming effect because the ignored stimulus and all other related concepts would have been categorized with a "do not respond" tag. Unrelated stimuli would not be encoded with a response tag, meaning there would be less of a negative priming effect for unrelated than related stimuli due to the need to overcome the contradiction between the current task and the previously encoded response requirements. Additionally, if interference from a previously ignored stimulus was the cause of the effect, there should have been a larger negative priming effect for the all-letters-colored than the single-letters-colored prime condition because all the probe letters were colored, making the all-letters-colored prime more similar to the probe, creating more interference when trying to overcome the do-not-respond tag (Marí-Beffa et.al., 2000).

A more likely, but not proven, theory that fits with these data is the distractor inhibition model. It allows for the lack of a relationship between the prime and probe words or non-words, as just the color is inhibited. When the participant responds to the

color in the prime trial, they suppress all other possible colors. When they are then required in the probe trial to respond to a different color that is now suppressed, they show longer reaction times due to their needing to overcome the inhibition (Marí-Beffa et.al., 2000).

The present study is based on Mayr et.al.'s (2006) experiment on auditory negative priming. It is predicted that that in an auditory Stroop-like task, negative priming effects will cause an increase in reaction times and decreased ERP positivity. When instructed to respond to one auditory stimulus that is presented at the same time as another auditory stimulus, then later respond to the previously ignored stimulus, it will take participants more time to respond. For example, if instructed to respond to a bird playing in the right ear and ignore a guitar playing in the left, then later told to respond to the guitar playing in the left and ignore a frog in the right, reaction times should be slower than if on the second presentation the participants must respond to a piano in the left and ignore a frog in the right, as found by Mayr et.al. (2006).

The preliminary hypothesis is that if negative priming is due to episodic retrieval, the effect should be larger for prime and probe stimuli from the same category than for stimuli from different categories. This is because when stimuli from the same category must be ignored, all related stimuli are encoded with a nonresponse tag. When prime and probe stimuli are categorically related, a conflict will occur because stimuli that are contextually similar will be encoded with both a respond and do-not-respond tag. Overcoming this conflict should be more effortful and time consuming. This effect should be evidenced by longer reaction times, an increased error rate, and decreased ERP positivity, especially in the parietal lobes (Mayr et.al., 2006).

Method

Participants

Data were obtained from 15 undergraduates, two males and 13 females from Houghton College who were either volunteers or receiving course credit for their participation. Five participants were excluded from the study due to errors that occurred in data collection, resulting in a final 10 participants, consisting of one male and nine females.

Stimuli and Procedure

The stimuli were digital sounds manipulated by a sound recording software to be of the same duration (300 ms) and volume. The sounds consisted of three musical instruments (piano, flute, and trumpet), and three animals (dog, cat, and frog). Stimulus presentation and timing were programmed using Neurobehavioral Systems Presentation ® software. The sounds were administered through headphones and a click was used to indicate to the participant to which ear they should attend.

Participants were seated in front of a computer screen with a black background and the words "Ready…". When instructed, participants pressed the Return key on a keyboard to start the trial. A white fixation cross was then present throughout the rest of the experiment to reduce ocular artifacts. After a 500 ms silence to establish the ERP baseline, a 20 ms click was played in either the right or left ear (Liotti, Noldorff, Perez III, & Mayberg, 2000). A 250 ms delay followed and then the prime pair of sounds played for 300 ms. Participants were instructed to press the up arrow key if the to-be-attended-to sound was an animal and the down arrow key if the sound was a musical

instrument. These keys were selected because it would reduce the spatial influence of the response keys. If the keys were located side-by-side, the target location (either left or right) could facilitate the pressing of the key on that side. Using keys that were arranged up-and-down should eliminate the effect (Mayr et.al., 2006). After a 1500 ms delay, a 20 ms click was presented in the opposite ear and after another 250 ms delay, the probe pair of sounds played (Mayr & Buchner, 2006; Yee et.al., 2000). A 1500 ms post-stimulus silence was then followed by the next trial (Lansbergen, van Hell, & Kenemans, 2007). Participants received no error feedback.

The experiment was structured by two negative priming conditions and one control condition. The methodology of the negative priming conditions includes two different auditory stimuli, such as the sound of a musical instrument and the sound of an animal, that are presented to the participant. A target sound was played in one ear while a distractor sound was played in the other ear. In the negative priming conditions, participants were asked to identify the target sound, meaning they should ignore the distractor sound. Then, the distractor sound was played as the target sound and participants identified it (Mayr et.al, 2006).

The first negative priming condition consisted of targets and distractors from the same category. The ignored distractor in the prime trial became the target stimulus in the probe trial, with the remaining two sounds being different. The four sounds of the prime and probe trials were either all animal or all instrument sounds. For example, a target sound of a frog played in the left ear while a distractor sound of a dog played in the right during the prime trial. Then in the probe trial, a cat was played in the left ear, being the distractor, and the dog became the target and was played in the right ear.

The second negative priming condition had targets and distractors from different categories. In the prime trial, the ignored stimulus was from a different category than the attended-to stimulus. In the probe trial, the previously ignored stimulus became the attended-to stimulus, with the remaining sound being different and from a different category. For example, the prime trial would consist of a trumpet in the left ear, being the target, and a dog in the right ear, being the distractor. The probe trial would then have a piano in the left ear, acting as the distractor, and a dog in the right ear, acting as the target.

The control condition had no repeated stimuli, and sounds could be from any category. For example, a flute would be the target sound and play in the right ear, while a dog would be the distractor in the left ear. Then in the probe trial, a cat would play in the left ear and be the distractor while a piano would be the target in the right ear.

There were 24 trials for each condition, resulting in a total of 72 trials. The sequence of trials was randomized across participants by moving the last pair of prime and probe trials for the previous participant to the beginning of the trial list of each condition for the next experiment. The conditions were given in the order of the negative priming condition with stimuli from the same category, followed by negative priming with stimuli from different categories, followed by the standard control trials.

Participants were instructed to respond as quickly and accurately as possible. They were told that the sounds would play automatically and that if they missed a response they should continue moving on to the next trial (see Appendix A).

Due to computer programming issues, a revised method was created in which only reaction times for stimuli presented in the left ear were analyzed. Due to an absence

of right-sided stimuli, the focus of the study changed to an investigation of the effect of categories on the positive priming effect. In this revised method, a click was presented in only the left ear to indicate the stimuli to which the participant should respond. Stimuli were presented simultaneously in the left and right ear as in the original method but only sounds in the left required a response.

At the end of the study, participants were given a short debriefing statement (see Appendix B).

EEG Recording

A BioSemi 64-channel EEG data acquisition system was fitted to each participant's head. EEG/ERP data collection and analysis was conducted with ActiveView® software, and statistical data analysis was completed using EMSE Suite ® software.

Similar to the study performed by Mayr et. al. (2006), the EEG sensors were placed in posterior and medial electrode clusters. Anterior sensors were not used because no effect was found in the original or related studies. The sensors measured the activity in the parietal, occipital and temporal lobes (Mayr et. al., 2006). Electrodes were also placed above and below the eyes to control for ocular artifacts, as well as on both right and left mastoids.

The 300-750 millisecond post-stimulus time window was the area analyzed for evidence of the negative priming effect, hypothesized to be evident by decreased ERP positivity (Mayr et.al, 2006). Reaction times were also measured. An ERP baseline was measured 500 ms prior to the presentation of the prime stimuli to average out noise and

use as a comparison for analysis of 1500 ms post-stimulus ERP effects (Liotti, et.al., 2000; Lansbergen, et.al., 2007).

EEG recordings and reaction times from the first five participants were excluded from the final data collection due to computer programming issues that showed up after the study was complete. ERP data was not collected for the remaining participants. Reaction time measures were retained.

Design

The original study was a 2x2x3 within-subjects factorial design with repeated measures. The independent variables were the three experimental conditions, the two types of stimuli (animal or musical instrument), and whether the attended sound was in the left or right ear. The dependent variables were the ERPs in the 300-750 millisecond range post-stimulus and reaction time measures. In the second revised study, the dependent variable was the reaction time measures, due to the discontinued use of the EEG. In the third and final revision, the independent variable was the experimental condition (same categories, different categories, standard control) and the dependent variable was the reaction time measures.

Results

Mean reaction times and standard deviations from the third revised study for each of the three conditions are shown in Table 1. The mean reaction times for each condition are illustrated in Figure 1. Analyses of mean reaction times for the 72 trials was conducted by a repeated measures ANOVA and determined that there were significant differences, ($F(2,18) = 7.203$, $p < .05$), in mean reaction times between the three conditions. Participants had significantly longer reaction times for stimuli from the same category.

	Mean	Std. Deviation	N
Same	701.2517	154.46799	10
Different	595.5567	70.22199	10
Control	561.0008	119.75716	10

Table 1. Means and standard deviations with number of participants (N) for each of the three experimental conditions.

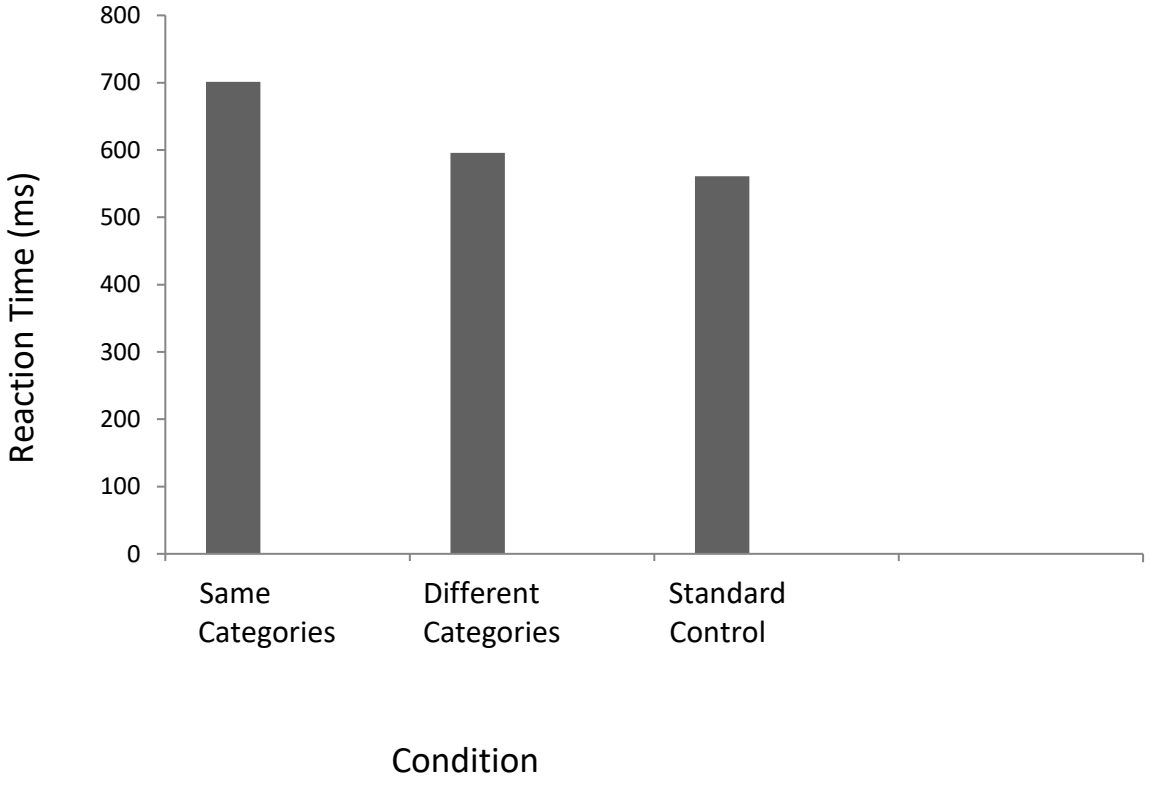

Figure 1. Graph of means for each of the three experimental conditions

Discussion

In conducting this study, three revisions of the method were necessary due to computer programming issues. The original method measured ERPs from five participants. About seven minutes, the amount of time required to listen and respond to all 72 trials, of ERP waveform data should have been automatically saved in each session. However, only 10 to 20 seconds of data were saved for each participant. Reaction time data was also missing. An attempt was made to only use the ten seconds that were recorded for each participant, but another computer error resulted in a lack of differentiation between response or trigger codes. It was impossible to determine if the participant responded with the Up arrow key, for an animal sound, or the Down arrow key, for a musical instrument sound. Instead, each participant's responses were recorded as if all triggers were pressed at the same time. As a result of the absence of separated response codes, it was impossible to average the ERP waveforms, yielding no analyzable data.

The second revision eliminated the use of the EEG and only used reaction time data. Because reaction times were still unable to be saved through the computer program, data were recorded by hand. While this technique increases the chance of incorrect recording, care was taken to ensure response codes and reaction times were accurate. However, at an undetermined point in data collection the sound stimuli were not correctly executed by the computer. A participant alerted the researcher that the click to indicate which ear to attend to was only presented on the left side. Due to time constraints, the cause of the programming error was not able to be determined and therefore the focus of the experiment rather than the stimulus presentation was changed. Results were not obtained to lend support to the hypothesis that a larger negative priming effect will be seen in the form of longer reaction times and decreased ERP positivity for stimuli from

the same category compared to stimuli from different categories due to these programming complications.

The third and final revision of the study used the computer program that only presented the click in the left ear. It was expected that the predicted priming effect would now be positive as a result of the changes to the method. If during the prime trial the stimuli were originally supposed to follow a right click, there would be no click and therefore the participant would not ignore the left sound. They would merely listen to both sounds and not respond. During the probe trial, the click would play in the left ear and the participant would cued to respond. However, because there was no click in the prime trial to cause the participant to ignore the left sound, it was predicted that they would experience a positive priming effect due to hearing and not ignoring the sound in the prime trial and then having to respond to that same sound in the probe trial. A negative priming effect was not expected to occur because the participant was not cued to ignore the left sound in the prime trial. Similarly, if the prime trial followed a left click, participants would ignore the sound presented in the right ear. However, the right click before the probe trial was absent, causing participants to not respond to any of the probe sounds. Because of this nonresponse, a measurement of the negative priming effect was thought to be unattainable.

There were significantly longer reaction times for trials consisting of stimuli from the same category compared to the standard control and trials consisting of stimuli from different categories. There were no significant differences between the mean reaction times in the same category negative priming condition and the different category negative priming and control conditions. The results can be interpreted as evidence of a negative

priming effect, rather than the predicted positive priming effect, for stimuli from the same category, due to the increased reaction times.

There are multiple implications for the negative priming effect for stimuli from the same category. It suggests that there are categorical effects of priming, consistent with the findings of Voss, Rothermund, Gast, and Wentura (2013) who found categorical effects of both positive and negative priming. When the prime stimuli were presented with the absence of a right click, the participant neither responded nor ignored the sounds. On the probe trial, a left click was present and participants responded, but these responses were slower than for trials using unrelated stimuli. It is interesting that a negative priming effect occurred only for stimuli from the same category. This could be due to how related stimuli are associated in memory.

According to episodic retrieval theory, stimuli and the responses made to the stimuli are encoded in episodes. When the prime trials occurred with a left click, the "respond" cue was encoded. However, when the prime trials did not require a response due to the absence of a click, no response would have been encoded with the stimuli. This then produced a negative priming effect because of the lack of any response tag associated with the primes. When responding later to the probe target, a conflict occurred between the required response and the encoded nonresponse. Due to the absence of a right click in the prime trials, this suggests that deliberate suppression of auditory stimuli is not necessary to establish a negative priming effect. Merely perceiving but not responding to a sound creates the effect, suggesting negative priming is very strong when stimuli are categorically related, similar to Mayr et.al. (2006).

Regarding the lack of a negative priming effect for stimuli from different categories, it is possible that when stimuli are from the same category, suppression of the probe response would occur only if the relationship between the prime and probe is strong enough. When the category is activated in encoding, such as the animal or instrument category, related stimuli are activated, allowing for a priming effect even in the absence of a response tag. There was no priming effect observed for different categories because with both the lack of categorical activation and absence of a response tag, inhibition would not occur. Therefore, it is possible that episodic retrieval can explain priming effects for categorically-related stimuli even when not previously encoded with a response, due to the categorical associations already present in memory, as seen in the results found by Mayr and Buchner (2003). This also suggests that merely perceiving strongly associated stimuli, even when not responding, can prime participants.

Unlike episodic retrieval, distractor inhibition does not adequately account for the negative priming effect in the present study. When a category is activated, all related stimuli are set in a state of excitation, regardless of whether a response was required. Similarly, when a stimulus is ignored, spreading inhibition suppresses all related categories. Therefore, this theory suggests negative priming should not be seen when stimuli are not suppressed. When the prime stimuli were presented without a click, participants did not inhibit the prime target, yet a negative priming effect still occurred, being inconsistent with this theory.

The lack of a negative priming effect for stimuli from different categories could result from a variety of factors. A lack of categorical associations would decrease the strength of the prime and probe relationship, as well as the priming effect, causing the

prime to not be strong enough to overcome other factors that occurred during the study (Mayr et. al., 2003).

Participants may have been confused by the absence of a right click when stimuli were played. This could create distraction and cause them to not attend to either of the sounds. This would reduce the likelihood that they would be primed to respond to the stimuli in the left ear on the next trial. Due to the lack of categorical activation seen for stimuli from the same categories, the prime was not strong enough to overcome this confusion. However, previous research has found that even subliminally primed auditory stimuli create a priming effect.

Kouider and Dupoux (2005) primed participants by playing a word or nonword that was compressed to be up to 50% shorter than its normal duration. The compressed prime stimuli were played simultaneously with a mask of compressed words played in reverse. The mask and compression caused the prime to be subliminal, or not consciously presented. Participants were instructed to decide whether the subliminal prime was a word or nonword. Results showed a significant increase in response times for primed word stimuli, suggesting the presence of a positive priming effect. This suggests that auditory priming can occur without participants being consciously aware of the prime stimuli (Kouider & Dupoux, 2005). Therefore, auditory primes can be consciously perceived even when attention is not immediately directed toward the prime stimulus. This suggests that the lack of significance of the present study is not due to confusion that distracts participants from the task. Because auditory prime stimuli still create priming effects when not consciously attended to, merely hearing the prime even if not consciously focused on it should produce an effect, even if not categorically related.

While Kouider and Dupoux's (2005) research suggest a priming effect would still be apparent for weak primes if participants were in a distracted state, their confusion about the lack of a right click may account for the absence of a positive priming effect with the weak priming structure of unrelated stimuli. Instructions were not given about how to respond to stimuli that are not preceded by a click. This may have caused participants to respond randomly and guess when there was no click, or it may have caused them to not respond at all. If participants guessed, the would be more likely to be correct if the prime and probe stimuli were from the same category, due to the stronger prime and increased activation. If guessing for stimuli from different categories, the prime would not be as strong, making it more likely for participants to be wrong when the primes and probes were from different categories. Future studies should include instructions about how to respond if the response cue is absent. The present study did not include more specific directions because the problem was not apparent until multiple participants completed the trials. In order to be able to use their data, the instructions could not be modified. Abstaining from using the data would have greatly decreased the amount of participants and it was unknown if the lack of direction in the event of an absence of a response cue would affect the results.

Another possibility is that the absence of a priming effect for unrelated stimuli was due to timing issues. Once again, primes that were related to their probes produced a strong enough priming effect to overcome timing issues, while unrelated primes and probes did not. Stimuli were presented rather quickly, with an interval of only 1500 milliseconds between the prime and probe stimuli. While this interval has been sufficient to gain a significant priming effect in previous research, several participants reported that

the task was difficult and the sounds were presented very quickly (Mayr & Buchner, 2006; Mayr et.al., 2006). It would be difficult in future research to reduce the prime-probe interval due to the time constraint of the priming effect. Research has shown that priming effects are strongest within 1500 milliseconds after the prime presentation, making it less likely an effect will be found if the prime-probe interval is lengthened. If an effect is found after the 1500 millisecond post-stimulus time range, it will likely not reflect the complete size of the priming effect, as it diminishes in strength (Mayr & Buchner, 2006). A possible compromise is an increased duration between each of the prime-probe trials, allowing participants to recover and prepare to respond to the next trial. This would not affect the priming effect because only the prime-probe interval is susceptible to time restraints. The time between separate trials should not affect responses within each trial (Mayr & Buchner, 2006).

In addition to an increased time interval between pairs of prime-probe trials, task difficulty could be reduced by preceding the experimental trials with practice trials. This would allow participants to become familiar with the task requirements and experience the sound stimuli before being tested. Presenting the sound stimuli separately may also have aided participants in more easily categorizing the stimuli, as first experiencing the stimuli in a negative priming situation could create additional unneeded difficulty.

This study also had an extremely skewed gender distribution. Reaction times for one male participant were recorded for the present study, compared to nine females. If males have faster reaction times to auditory stimuli, having more male participants may have decreased the mean reaction times and possibly would have shown a small but significant priming effect. Future research should have an equal number of male and

female participants to make up for the discrepancy between average reaction times. The differences in auditory reaction times between males and females should also be investigated.

The results from the present study provide many prospects for future research. Subliminal auditory priming with categorical comparisons would show how strong the categorical priming effect is. If related stimuli are more readily primed when subliminally perceived compared to unrelated stimuli, further evidence for how objects are associated in memory as well as the role of categorical activation in retrieval could be shown. Comparing priming effects for primes with and without a response requirement is another prospective avenue for research. This would clarify whether the encoding of a response tag is more facilitative for later responding or if it is a relatively unnecessary component of priming studies. Determining the role that encoded response tags play could clarify how episodic retrieval operates and how best to prime or encode stimuli.

Although the results of the present study showed no effect for unrelated prime and probe stimuli, further research in this area is worthwhile. There is significantly more research on negative priming in the visual compared to the auditory domain, despite the fact that numerous studies have shown auditory simple reaction times to be significantly faster than visual simple reaction times. Shenvi and Balasubramanian (1994) found that reaction times to visual stimuli in the form of red and green lights were significantly slower than reaction times to auditory stimuli in the form of high and low pitches. There was also no significant difference between reaction times to the different pitches, while there was a significant difference in response to the green compared to the red light. Ng

and Chan (2012) found auditory reaction times to be up to 5% faster than visual reaction times.

The faster auditory reaction times could be contributed to a decreased distance between the receiving organ and the auditory and motor cortex. The distance from the ear to the auditory cortex determines how fast a stimulus is processed, while the distance to the motor cortex determines how fast a response to the stimulus can be made. It takes an average of 10 milliseconds for auditory stimuli to be perceived by the brain, compared to between 20 and 40 milliseconds for a visual stimulus. As a result, reaction times are potentially faster to auditory stimuli due to the decreased time needed to perceive the stimuli (Shenvi & Balasubramanian, 1994; Shelton & Kumar, 2010).

The more efficient perception of auditory stimuli makes it an important modality to further explore in relation to the negative priming effect. It would be more difficult to hit a ceiling effect when using auditory rather than visual stimuli in a negative priming task. The visual modality has less potential to show a large priming effect because reaction times are typically slower than auditory reaction times. If a large negative priming effect can be created in the auditory modality, it stands to reason that a similar or identical method could be used to create the effect in the visual modality. However, due to the naturally longer reaction times to visual stimuli, a negative priming effect for visual stimuli may not reach significance in the auditory modality. A stronger prime is needed for auditory stimuli to show an effect. Once a sufficiently strong prime is found, it may be able to generalize to other, less efficiently perceived modalities and still retain its effect.

Positive priming research has been studied relatively in depth in relation to categorical effects. Multiple studies have been conducted that establish a significantly larger priming effect when responding to related than unrelated stimuli. Bazzanella and Bouquet (n.d.) showed a significantly larger priming effect for associated than unassociated stimuli. Voss, Gast, Rothermund, and Wentura (2013) also found a significant categorical priming effect for semantic stimuli in lexical decision tasks. Categorically matched prime and probe stimuli facilitate responding and result in faster response times. These effects have been studied in the auditory domain as well, as evidenced by Bermeitinger, Wentura, Koppermann, Hauser, Grass, and Fring's (2012) study of "masked category primes in audition."

Categorical negative priming in the auditory domain, unlike categorical positive priming, is an area of research that would benefit from additional exploration. Research on auditory negative priming has not been investigated as thoroughly as positive priming, especially in relation to categorical effects. Understanding this field more completely will aid in determining the underlying mechanism of the negative priming effect. Current research provides relatively equal evidence for both distractor inhibition theory and episodic retrieval theory. Expanding research into the auditory domain of categorical negative priming may clarify whether episodic retrieval can account for the effect, or if spreading inhibition is a more likely cause. Episodic theory could be supported by determining if there is evidence for long-term effects of auditory negative priming. Distractor inhibition only spreads for a small time period after the act of inhibition, peaking at about 450 milliseconds post-stimulus and thenceforth diminishing in strength (Liotti et.al., 2000). Therefore, strong effects found at a later time could be attributed to

episodic retrieval, as the nonresponse tag should be encoded with a stimulus until a different response is necessary, which then alters the formerly encoded response after the conflict is resolved.

Although the present study did not find any significant negative priming effects for categorically unrelated stimuli, it did show a significant effect for related stimuli and introduces an important subject for further research. Episodic retrieval theory best explains the results of the present study. A modified version of this study may indicate the degree to which categorically related auditory stimuli create a larger priming effect than categorically unrelated stimuli, helping clarify if distractor inhibition is able to explain the effect in some other way. Once this can be determined, a new field of research into the proven theory would become available.

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Appendix A

Instructions recited to participants before starting the experiment:

In this experiment you are going to be listening to and categorizing sounds. I am going to give you headphones to wear. When the experiment starts, you will hear a click in one ear, either your left or your right. Then, you are going to hear two sounds playing, one in your left and a different one in your right. You should only pay attention to the sound that is on the same side that the click was on. You are going to categorize that sound as either an animal or a musical instrument. If it is an animal, press the Up arrow key. If it is an instrument, press the Down arrow key. Sounds will be presented rather quickly, so make sure you are paying attention. Remember to only listen and categorize the sound that is on the same side as the click – ignore the other sound. Try to respond as quickly but accurately as possible. During the experiment, try to look at the white cross in the middle of the computer screen. It is there to help keep you from getting distracted. When I instruct you to do so, you will press the Return key to start the sounds playing, and after that the sounds will continue playing automatically until the end. At the end of the experiment, the program will stop by itself. Are there any questions?

Appendix B

Debriefing statement recited to participants at the end of the study:

This experiment was conducted to test the negative priming effects of auditory stimuli. Negative priming is a psychological phenomenon that occurs when you must attend to a previously ignored stimulus. When you ignore something on its first presentation, and then have to respond to it later, reaction times are usually slower. I was studying particularly the effects of categories on the negative priming effect. You were presented a pair of sounds and asked to categorize one sound while ignoring the other sound. On the next pair, the sound you ignored previously was the sound you had to categorize. This experiment will show if there is a larger negative priming effect for stimuli from the same category than for stimuli from different categories. If you would like more information about the study, or would like to receive the results of the study, please contact me at meghan.mccuistion15@houghton.edu