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Temporal Negative Priming: Visual and Auditory

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Temporal Negative Priming: Visual and Auditory

Empirical Research Honors Thesis

Presented to

The Faculty of the Department of Psychology

Bates College

In partial fulfillment of the

Requirement for the degree of the

Bachelor of Arts

By

Alexa C. M. Harrison

Lewiston, Maine

[March 20th, 2019]

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Table of Contents

Abstract	5
Temporal Negative Priming: Visual and Auditory	6
<i>Present Study</i>	10
Experiment 1	11
<i>Methods</i>	11
Participants	11
Procedure	11
Conditions	13
<i>Results</i>	16
Confounded Temporal Position and Response Analysis.	18
Isolated Temporal Position Analysis	18
Isolated Response Data	21
Relationship Between Negative Priming and Individual Difference Variables	22
<i>Discussion</i>	23
Summary of Results	23
Next Area of Research	25
Experiment 2	28
<i>Methods</i>	29
Participants	29
Procedure	29
Conditions	30
<i>Results</i>	30
Isolated Temporal Analysis	30
Isolated Response Analysis	32
<i>Discussion</i>	33
Summary of Results	33
Next Area of Research	37
Experiment 3	41
<i>Methods</i>	41
Participants	41
Procedure	41
<i>Results</i>	42
Confounded Trials	42
Isolated Temporal Analysis	45
Isolated Response Analysis	46
<i>Discussion</i>	47
Summary of Results	47
General Discussion	52
<i>Summary of results</i>	52
<i>Limitations of this study</i>	55

TEMPORAL NEGATIVE PRIMING	4
<i>Future Areas of Research</i>	56
<i>Concluding Remarks</i>	58
References	60
Appendix	67
<i>Experiment 1 Consent Form</i>	67
<i>Experiment 1 Debriefing Form</i>	68
<i>Experiment 2 Consent Form</i>	69
<i>Experiment 2 Debriefing Form</i>	70
<i>Experiment 3 Consent Form</i>	71
<i>Experiment 3 Debriefing Form</i>	72

Abstract

Recently Kahan, Slowiaczek, and Altschuler (2017) reported a new form of negative priming, termed temporal negative priming. The purpose of the current study was to first replicate this effect using a slightly altered methodology and then to examine possible mechanisms that contribute to temporal negative priming and the extent to which this effect might generalize across modalities. By requiring participants to attend to both the distractor and target stimuli, the first experiment found robust temporal negative priming effects. The second study explored whether temporal negative priming is in part caused by difficulty binding features of a target with a temporal position that was previously associated with features of a distractor (Park & Kanwisher, 1994). Results were inconclusive but are consistent with the possibility that feature mismatch theory may not be the causal mechanism behind this effect. In addition, the data support memory-based over inhibition-based theories, but additional research is needed to determine if this memory-based negative priming effect is sensitive to manipulations which affect memory retrieval. The final study found temporal negative priming within the auditory modality as well. Fifty-seven individuals participated in the first experiment, 49 individuals participated in the second experiment and 38 individuals participated in the final experiment. Similar to other negative priming studies, participants were shown prime-probe trial pairs. However, in all of the studies reported here, prime-probe trial pairs were shown at different timing sequences to help separate the effects of temporal location and response.

Temporal Negative Priming: Visual and Auditory

Individuals are constantly exposed to far more detail than they can process at one time and the ability to distinguish between relevant and irrelevant information requires a fair amount of cognitive control. In fact, in many circumstances learned and reflexive associations are incompatible with the behavior that is needed, and in these situations top-down cognitive control is engaged (Braver, 2012). Negative priming experiments require control of this sort and results may help to clarify the mechanisms involved in ignoring distraction. Negative priming is the finding that reaction times (RTs) to a stimulus are significantly slowed if that stimulus was previously ignored. This is a well-researched and robust effect found across several modalities such as vision (Tipper, 1985; May, Kane, & Hasher, 1995; Schrobsdorff, Ihrke, Behrendt, Herrmann, & Hasselhorn, 2012), audition (Mayr & Buchner, 2006; Mayr, Buchner, Moller, & Hauke, 2011) and even tactile senses (Frings, Mast, & Spence, 2014). Experimental trials for negative priming generally contain a prime-probe pairing. During the prime trial, participants are shown both a target and distractor stimulus and are required to respond to the target. In the probe trial participants are either shown a target and distractor or simply a target to which they are required to respond. Research has consistently indicated that when the target stimulus from the probe trial originally appeared as the distractor stimulus from the prime trial, participant responses are significantly slower and more prone to error compared to control trials (Dalrymple-Alford & Budayr, 1966; Tipper, 1985).

Negative priming effects have traditionally been broken into two major categories: spatial and identity. Spatial negative priming indicates that when a probe target is placed in the same location on a display as the prime distractor, participants will have significantly slower RTs than if the probe stimulus appears in any other location (Tipper, Brehaut, & Driver, 1990; Neill &

Kleinsmith, 2016). Conversely, identity-based negative priming occurs when a participant is asked to identify a target while ignoring the identity of a distractor (Tipper, 1985). In subsequent probe trials, research has shown that participants are significantly slower to identify a probe-trial target if that item's identity had previously appeared as a distractor during the prime trial.

Negative priming research might provide clues about the mechanisms involved in selective attention. This is particularly important considering certain groups with attentional deficits exhibit diminished negative priming and may have impaired cognitive control. For example, individuals with schizophrenia, Alzheimer's disease, ADHD or depression show decreased levels of negative priming (Vaughan, Hughes, Jones, Woods, & Tipper, 2006; Ungar, Nestor, Niznikiewicz, Wible, & Kubicki, 2010; Macqueen, Galway, Goldberg, & Tipper, 2003; Ossmann & Mulligan, 2003; Frings, Wentura, & Holtz, 2007). In the case of individuals with Alzheimer's disease, a significant decrease was found for identity negative priming but not for spatial negative priming, indicating that these two types of priming reflect different attentional mechanisms (Vaughan et al., 2006). Negative priming likewise diminishes for other groups such as frequent cannabis users (Albertella, Le Pelley, & Copeland, 2016). Albertella et al.'s (2016) study further indicated that this reduction in spatial negative priming is gender specific and only impacts women. Brain imaging, using fMRI, has also found that negative priming is linked to specific activation in the brain and a decrease in negative priming is reflected in shifts in brain area activation (Ungar et al., 2010). More specifically it was found that identity-based negative priming is linked to activation only in the right dorsolateral prefrontal cortex for individuals without schizophrenia, whereas activation from identity-based negative priming occurs in both the right and left dorsolateral prefrontal cortex for individuals with schizophrenia (yet despite this increased activation these individuals did not exhibit the negative priming slowdown). This

research indicates that not only can certain forms of negative priming be linked to certain areas of the brain, but a decrease in negative priming and cognitive control can also be linked to a different pattern of brain region activation. Further research into negative priming can help to provide a greater understanding of the mechanisms behind this cognitive control and the implications that a decline in this cognitive control may have for mental illnesses.

Most of the current research revolves around the two major categories of negative priming and the implications they have for different forms of cognitive control. However, a recent study by Kahan, Slowiaczek, and Altschuler (2017) indicates that there is a third category, termed temporal negative priming, which is distinct from identity and spatial negative priming. Temporal negative priming is the finding that participants are slower or less accurate to respond to a target when it had previously appeared at a point in time which was associated with a distractor. Their study utilized rapidly flashing boxes located in the center of the screen to create distinct temporal positions with target and distractor stimuli. Although the results of this paper were promising for this new type of negative priming, there were a few limitations which will be addressed in the present study.

Kahan et al. (2017) were the first to show this type of negative priming, but there were minor inconsistencies with the data. During their first experiment, significant negative priming was only found for the RT data but this effect was not reproduced within the accuracy data. For the replication experiment, significant negative priming was observed in the accuracy data but not the RTs. Although temporal negative priming was observed in both experiments, some may be concerned that the effect is somewhat small since it was not reliably observed in both RTs and accuracy rates. A further step to evaluate whether temporal negative priming occurred in Kahan et al.'s (2017) data was to conduct an error protection analysis. First utilized by Buckolz,

Stoddart, Edgar, and Khan (2014), their research found that when participants made an error in a spatial negative priming task, they were less likely to make an error associated with the distractor location from the prime trial than any other location. This was attributed to residual inhibitory factors from encoding the distractor stimulus, and therefore its location, as something to avoid. By evaluating the types of errors individuals make, it is possible to gain additional evidence for temporal negative priming. In fact, when this analysis was conducted on Kahan et al.'s (2017) data they found strong evidence in favor of error protection. When errors were made on control trials, their participants were more likely to respond with temporal locations which had not contained a distractor stimulus on the prime relative to any other temporal positions. These results were found in both their first experiment and their replication experiment. The evidence from the RT data from their first experiment, the accuracy data from the replication experiment, and the presence of error protection in both provides a strong indication that temporal negative priming exists as a third new form of negative priming, although the effects may be relatively small. In the present study, the purpose of Experiment 1 is to enhance the effects already found by Kahan et al. (2017).

One way of increasing temporal negative priming would be to require that participants attend to both the target and the distractor during the prime trial. A study conducted by MacDonald, Joordens, and Seergobin (1999) examined this same possibility in an identity-based negative priming task. In their study, participants were shown the names of two animals overlaid upon each other. During the prime trial, participants were requested to identify which of the two animals was the largest in real life, ensuring that participants were processing both items before deciding which image would be the target and the distractor. For example, if people were shown the words goat and mouse on the prime trial, they were much slower to respond to the word

mouse on the probe trial if they were then shown mouse and flea. The results of this study found that the addition of attending to both the target and distractor quadrupled the negative priming effect compared to the standard negative priming effect of 15 to 25 ms reported by Fox's (1995) review of the negative priming literature. This marked increase in the effects of negative priming was mirrored in a similar study conducted by Kahan, Mathis, and Jackson (2002). In this experiment, participants engaged in a Stroop task where the first group participated in a standard Stroop task, the second group was asked to recall the distractor word from the prime trial on 12.5% of the trials, and the final group was asked to recall the prime distractor word on 87.5% of the trials. This procedure ensured that participants were attending to both the word and color of the stimulus on the prime trial. Results indicated that participants who were required to recall the prime on 87.5% of the prime-probe trial pairs experienced negative priming effects that were seven times greater than participants who were only engaged in the standard Stroop task. By applying similar methods of required attention to both the target and distractor stimuli, this study may enhance the amount of temporal negative priming first reported by Kahan et al. (2017; but see Joordens, Betancourt, & Spalek, 2006 for data that suggest this manipulation does not always enhance the negative priming effect).

Present Study

The primary goal of Experiment 1 is to amplify the temporal negative priming effects reported by Kahan et al. (2017) using a technique that has magnified other types of negative priming in the past. Research has indicated that focusing on both the prime and distractor during the prime trial can significantly increase negative priming and for this reason the task was modified to include this requirement (MacDonald et al., 1999; Kahan et al., 2002). Once the magnitude of temporal negative priming has been sufficiently raised, Experiment 2 will explore

whether temporal negative priming may occur because individuals have difficulty binding features of a target to a temporal position associated with different features (i.e., feature mismatch). Finally, Experiment 3 will attempt to extend this effect to the auditory modality. It is hypothesized that in Experiment 1, temporal negative priming will be found in both RTs and accuracy rates by using a similar methodology to that of MacDonald et al. (1999) and Kahan et al. (2002).

Experiment 1

Methods

Participants. The participants for this study were taken from introductory and intermediate psychology courses at Bates College. Overall, data were collected for 57 participants. However, due to an overwriting error, only 56 sets of data were analyzed. Forty females and 16 males completed this study in exchange for extra credit for their courses ($N = 56$). The participants ranged in age from 17 to 21 years with an average age of 19.

Procedure. The procedure of Experiment 1 mirrored that of Kahan et al. (2017) with a few key differences. Participants were seated approximately 60 cm away from the screen and the display was set to the 'aspect' resolution. BenQ monitors were used and the refresh rate was set at 120 Hz. Prior testing (with a photodiode) of the monitors that were used in this and subsequent experiments show that these BenQ LCD monitors have a shorter rise and fall time than CRT monitors, a finding that is in agreement with Lagroix, Yanko, and Spalek (2012). In this study, E-prime 2.0 software (Schneider, Eschman, & Zuccolotto, 2012a; 2012b) was used to display 204 prime-probe paired trials to participants. The first four alternating paired trials were practice while the remaining 200 were experimental. During each trial, participants were shown a box in

the center of the display. This box was flashed on the screen four times according to a predetermined timing sequence. For the prime trial, one box contained a target (X), one contained a distractor (O) and the remaining boxes were blank. At the beginning of the prime trial, participants were asked to focus on which boxes contained both the target and distractor stimuli. Once the trial sequence was complete, a “?” was shown and participants indicated the location of the target X (either in box 1, 2, 3, or 4) as quickly and accurately as possible. Responding to the temporal position of the X mirrored the procedure used by Kahan et al. (2017).

During the probe trial, participants again were shown another sequence of four boxes which flashed in the same location. No distractors were present so participants viewed either a blank box or a box containing an X. At the end of this sequence, participants indicated which box contained the target when a “?” was flashed using the 1, 2, 3, and 4 keys. Participants responded as quickly and accurately as possible. However, unlike the procedure of Kahan et al. (2017), after a prime-probe paired trial, participants were asked to identify when the O was shown during the prime trial to ensure participants were attending to both the target and the distractor. This response was signaled with a display that read “When was the O?” and this was done on 88% of the trials. Participants were asked to press the eight key to move on to the next trial on the remaining 12% of trial pairs.

For both the prime and probe trials, participants were shown the boxes either in a rapid sequence or a slow sequence. Consistent with the procedure conducted in the Kahan et al. (2017) study, participants saw a fixation point for one second. After the fixation point, participants were shown the first box, a blank screen, the second box, a blank screen etcetera until the sequence was completed. The boxes appeared for 250 ms in both fast and slow sequences. For the fast

trials, each box was separated by a 250 ms blank screen. For the slow trials, each blank screen was shown for 750 ms in between each box. Having the speed of the prime and probe trials vary made it possible to tease apart the effects of temporal position from the effects caused by an ignored response, the two of which are confounded when the prime and probe are shown at the same rate of speed.

At the end of the experiment, participants were asked a number of demographic questions. They were reminded that their answers are completely anonymous and that they could skip any questions which made them uncomfortable. The first several demographic questions covered basic information about age and gender. The next question asked participants how often they ingest marijuana in any form on a gradient scale (daily, weekly, monthly, yearly, and never). Using the guidelines Albertella et al. (2016) set, we identified frequent cannabis users as those who have ingested cannabis, in any form, at least weekly for the last six months. Participants were reminded that they should respond honestly and that their answers were anonymous since names were never linked with participant numbers. Participants were then asked if they have a history of any of the following mental health issues: Alzheimer's disease, schizophrenia, ADHD, or depression. The experiment concluded with participants taking a 32 question schizotypal personality questionnaire-brief revised (updated) (SPQ-BRU) taken from Davidson, Hoffman, and Spaulding (2016). In total, this experiment lasted 45 minutes.

Conditions. Participants were exposed to four timing sequences: 1.) fast prime trial and fast probe trial; 2.) fast prime trial and slow probe trial; 3.) slow prime trial and fast probe trial; 4.) slow prime trial and slow probe trial.

This methodology, which was used by Kahan et al. (2017), was developed by Neill and Kleinsmith (2016) in a spatial negative priming task and nicely allows the effects of positioning

to be separated from effects of the response. On each trial the probe target could 1.) appear in the same temporal location as the prime target (the Attended Position); 2.) appear in the same temporal location as the prime distractor (Ignored Position); 3.) require the same response as the prime target (Attended Response); 4.) require the same response associated with the prime distractor (Ignored Response) or 5.) have the prime and probe be unrelated to each other (Unrelated).

This created three possible sequencing scenarios for the same-timing sequences (depicted in Figure 1):

- (A) Attended Position + Attended Response
- (B) Ignored Position + Ignored Response
- (C) Unrelated Control

This also created seven possible sequencing scenarios for the different-timing sequences (depicted in Figure 1).

- (D) Ignored Position + Attended Response
- (E) Attended Position + Ignored Response
- (F) Ignored Position (different response)
- (G) Attended Position (different response)
- (H) Ignored Response (different position)
- (I) Attended Response (different position)
- (J) Unrelated (including “position controls”)

Temporal Position/Response		Temporal Position				Response			
Prime	Probe	Prime	Probe	Prime	Probe	Prime	Probe	Prime	Probe
X		X		X		X		X	
									X
O	X	O	X	O	X	O	X	O	
								X	

Figure 1: This figure is a visual representation of the different timing sequences which participants could experience throughout the experiment. The first two columns depict the conditions in which temporal position and response are confounded (condition B). The middle two columns indicate trials where the effects of temporal position have been separated from the effects of response (condition F). The final two columns indicate trials in which the effects of response have been isolated from temporal position (condition H).

A comparison of conditions B and C shows temporal negative priming effects when the effects of temporal position are confounded with the effects of an ignored response. This is due to the fact that the target on the probe requires the same response and appears at the same temporal position as the prime distractor. A comparison of conditions F and J shows temporal negative priming when the effects of temporal position are isolated from the response. In these cases, the probe target appears at the same temporal position (relative to the fixation point) as the prime distractor but requires a different numeric response than the prime distractor. Finally, a comparison of conditions H and J shows temporal negative priming effects when the effects of the ignored response are isolated from the effects of the temporal position. In these cases, the probe target and the prime distractor require the same numeric response but occupy different temporal positions in relation to the fixation point. When the ignored position (condition F) and unrelated (condition J) comparison was made, only unrelated trials where the target on the probe appears at a possible prime position were used since this must be the case in the ignored position

condition. However, when the ignored response (condition H) and unrelated (condition J) comparison was made, the unrelated trials were not restricted in this way because the ignored response trials did not always have a target appearing in a possible prime position. These are the same comparisons that were made by Kahan et al. (2017) as well as Neill and Kleinsmith (2016).

Results

All of the data are presented in Table 1. Accuracy data from trials where participants did not correctly identify the prime target were discarded. For the RTs, trials where participants did not correctly identify both the prime target and probe target were discarded. To minimize the influence of long RTs, log RTs were examined and the mean log RT for each subject in each condition was computed. By doing this, all RTs in each condition had an influence on the means (rather than labeling some values as spurious using an arbitrary cutoff) but the influence of excessively long RTs was minimized. From this, the anti-log of the mean values was calculated (i.e., this is a geometric mean) and these geometric mean RTs were treated as the dependent variable in the ANOVAs reported. Geometric means of this sort have the benefit of being in the same millisecond (ms) scale while reducing the influence of outliers (rather than discarding these values) and geometric means of this sort have been used elsewhere in the literature (Neill, Lissner, & Beck, 1990).

Table 1. Mean Reaction Times (RT) and Proportion Errors (PE) in Experiment 1 along with 1 standard error of measure (SEM).

Prime-Probe Relation	Temporal Sequence of Prime Trial								Marginal Means			
	Fast				Slow							
	RT	SEM	PE	SEM	RT	SEM	PE	SEM	RT	SEM	PE	SEM
Temporal Position and Response Repetition												
Ignored	497	26	.12	.02	422	22	.08	.02	459	21	.10	.02
Unrelated	502	25	.12	.02	481	59	.11	.02	492	37	.12	.02
Negative Priming	-05		.00		-59		-.03		-33		-.02	
Temporal Position Alone												
Ignored	516	28	.17	.03	524	32	.14	.03	520	28	.15	.02
Unrelated	480	26	.15	.03	435	24	.09	.02	457	22	.12	.02
Negative Priming	36		.02		89		.05		63		.03	
Response Repetition Alone												
Ignored	531	53	.09	.02	559	42	.14	.03	545	39	.11	.02
Unrelated	467	24	.12	.03	477	23	.13	.02	472	22	.12	.02
Negative Priming	64		-.03		82		.01		73		-.01	

Confounded Temporal Position and Response Analysis. The first category of prime-probe trials contained sequences in which the temporal positioning of the stimuli and responses were confounded, as seen in Figure 1. This encompassed both conditions B and C since the prime and probe trials were either fast-fast or slow-slow. The accuracy data from these situations were analyzed in a 2 (speed: fast-fast vs. slow-slow) x 2 (prime-probe relationship: ignored repetition vs. control) repeated measures analysis of variance (ANOVA). There was a significant main effect of speed in the accuracy data, $F(1,55) = 5.88$, $p = .019$. This indicates that participants were significantly more accurate in the slow-slow sequences ($M = .91$) than in the fast-fast ($M = .88$) sequences, as seen in Figure 2. No other significant results were found in the RTs or accuracy.

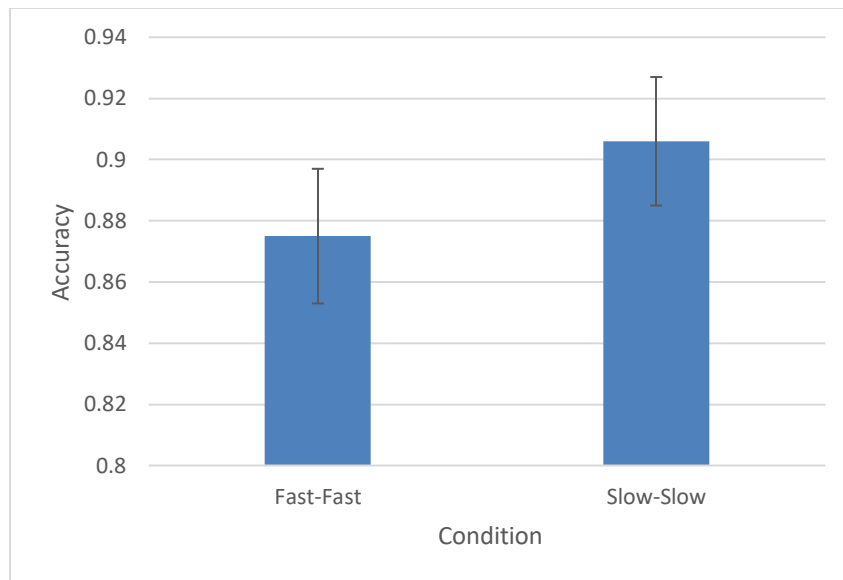


Figure 2: This figure depicts the main effect of speed (fast-fast vs. slow-slow) found within the confounded trials (conditions B and C). Error bars represent 1 SEM.

Isolated Temporal Position Analysis. The RTs and accuracy data for prime-probe sequences which isolate temporal position from the effects of response can be seen in Figure 3. The same 2 (speed: fast-slow vs. slow-fast) x 2 (prime-probe relationship: ignored repetition vs. control) repeated measures ANOVA was conducted on the accuracy data of their sequences (F

and J). A significant main effect for speed was found in the accuracy data, $F(1,54) = 4.22$, $p = .045$, indicating that participants were more accurate in the slow-fast trials ($M = .88$) than in the fast-slow trials ($M = .84$).

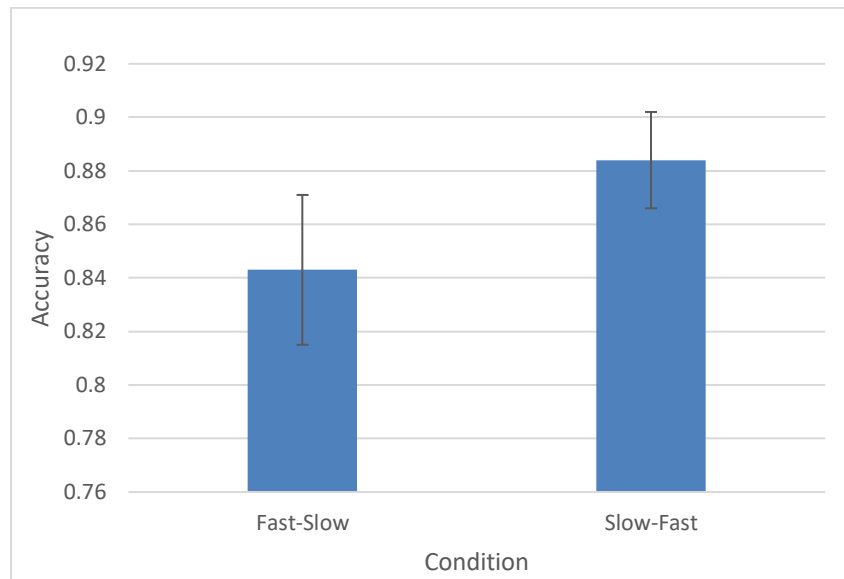


Figure 3: This figure depicts the difference in accuracy between the fast-slow and slow-fast trials within the isolated temporal position trials (conditions F and J). Error bars represent 1 SEM.

A second significant main effect was found for negative priming in the accuracy data, $F(1,54) = 5.35$, $p = .025$. Participants were less accurate on ignored repetition trials ($M = .85$) than control trials ($M = .88$). However, no significant interaction between speed and negative priming was found.

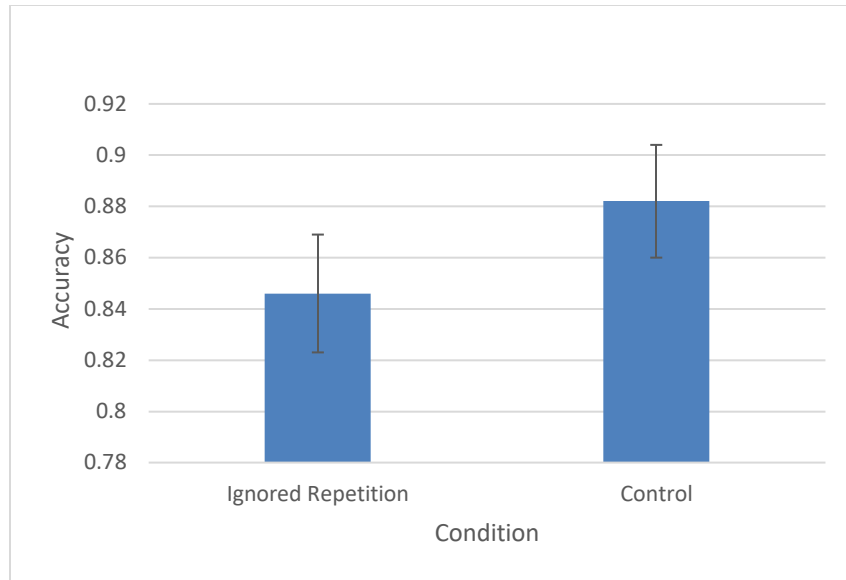


Figure 4: This figure depicts the difference in accuracy between the ignored repetition and the control trials for the isolated temporal position trials (conditions F and J). Error bars represent 1 SEM.

The RT data of these sequences (F and J) were analyzed in the same manner using a 2x2 repeated measures ANOVA. A significant main effect was found for negative priming $F(1,51) = 10.30, p = .002$.

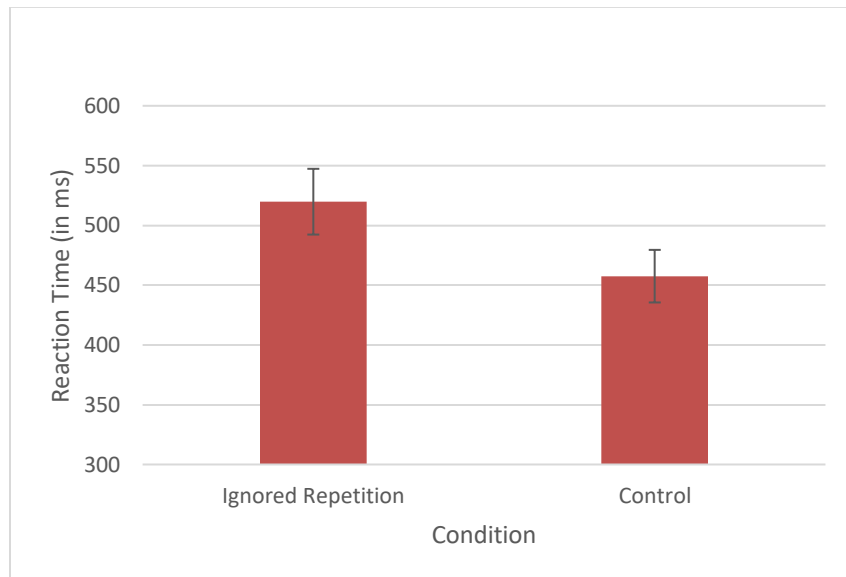


Figure 5: This figure represents the main effect found between the ignored repetition and control conditions for the isolated temporal position data (conditions F and J). Participants were an average of 63 ms slower in the ignored repetition condition than the control. Error bars represent 1 SEM.

Participants were significantly slower to respond to the target on the probe trial when a distractor from the prime was associated with that temporal position ($M = 520$ ms) than situations where the target on the probe was unrelated to the distractor from the prime ($M = 457$ ms). No interactions were found. Importantly, negative priming was observed in both the accuracy rates and RTs.

Isolated Response Data. Data collected from prime-probe sequences where ignored response was tested independently from temporal position (sequences H and J as seen in Figure 1) were analyzed in the same 2×2 repeated measures ANOVAs. A significant main effect was found for speed in the accuracy data denoting higher accuracy in the fast-slow conditions ($M = .90$) than in the slow-fast conditions ($M = .87$), $F(1,55) = 4.11$, $p = .047$.

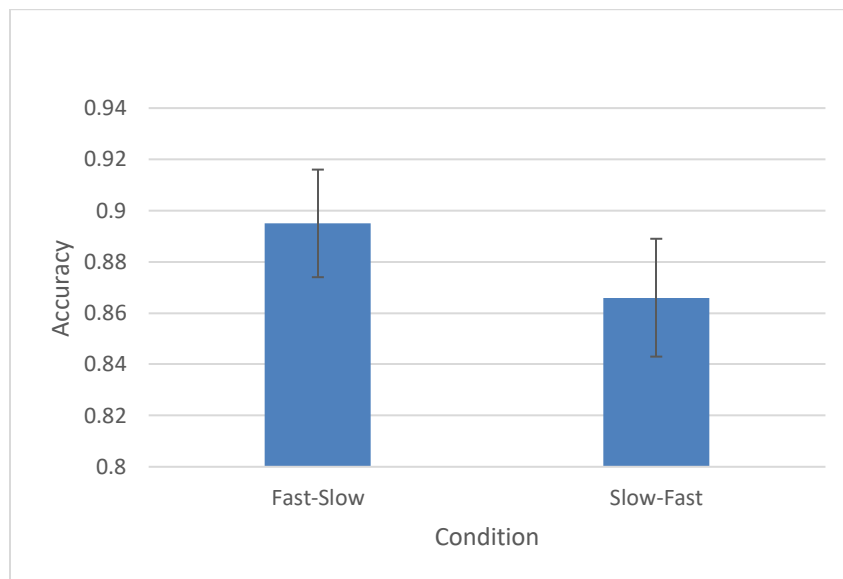


Figure 6: This figure depicts the difference in accuracy between the fast-slow and slow-fast trials for the isolated response data (conditions H and J). Error bars represent 1 SEM.

No other significant interactions or main effects were found for the accuracy data. However, a significant main effect was found for negative priming in the RT data, $F(1, 54) = 7.39$, $p = .009$. This indicates that individuals were slower to respond in the ignored repetition trials ($M = 545$

ms) than in the control trials ($M = 472$ ms). No other significant main effects or interactions were found in the RT data for sequences H and J.

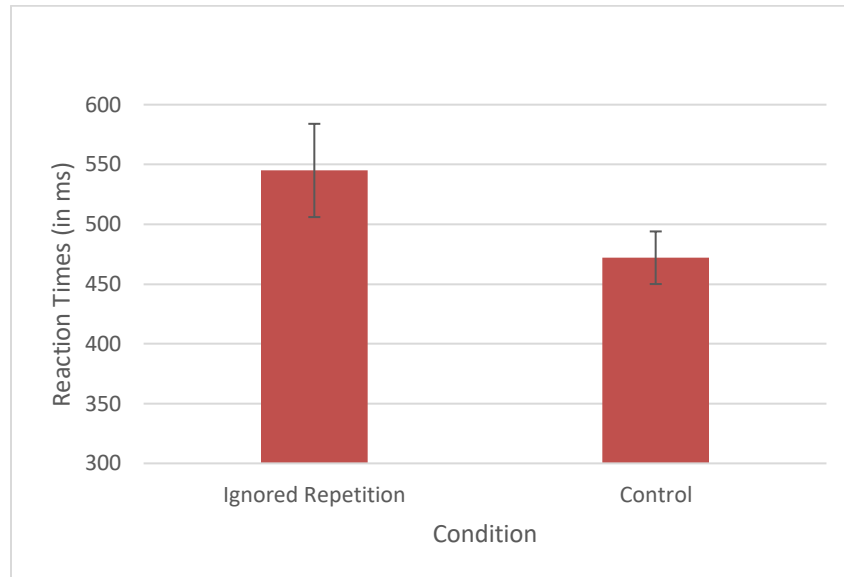


Figure 7: This figure represents the differences in RTs (in ms) between the ignored repetition condition and the control condition for the isolated response trials (conditions H and J). Participants were an average 73 ms slower in the ignored repetition conditions than the control. Error bars represent 1 SEM.

Relationship Between Negative Priming and Individual Difference Variables. The responses to the SPQ-BRU and marijuana questionnaires were analyzed and correlations between these scores and temporal negative priming were assessed. The SPQ-BRU questionnaire utilized a 5-point Likert scale where 1 designated a lower schizotypal trait, 5 designated a higher trait and 0 indicated a skipped question. The scores for each participant were tallied, with potential scores ranging from 0 (no schizotypal traits) to 160 (high schizotypal traits). Participant scores ranged from 49 to 109 with a mean of 76 points. Though scores on this scale varied by 60 points this only captures 37.5% of the total range possible and as such correlations with this measure might be artificially reduced. There was a larger range of responses for marijuana usage. The number of times a year each participant ingested marijuana was calculated and our

participant scores met the full range of 0 to 365 days a year with a mean of 41 days a year.

Despite the range of scores, both of these measures failed to produce any correlation with any of the measures of negative priming (the confounded condition, the isolated temporal position conditions or the isolated response conditions) and therefore these measures were removed from subsequent experiments.

Discussion

Summary of Results. The data from Experiment 1 indicate that participants experienced temporal negative priming. The mechanism responsible for this (whether it is time-based or response-based) can partly be identified by examining isolated response and isolated temporal position trials along with trials where these two were confounded. For isolated response trials, the distractor stimulus from the prime trial and the target stimulus from the probe trial required the same numeric response but were situated in different temporal locations. In these trials, participants were found to have significantly slower response times for the ignored repetition trials than the control trials, indicating that a response-based mechanism must play a role. Buckolz, Edgar, Kajaste, Lok, and Khan (2012) make the argument that spatial negative priming is caused by participants actively inhibiting the distractor response during the prime trials. According to the response inhibition theory, the response associated with the distractor is inhibited during the prime trial, and this inhibition makes participants slower to react to targets that require this response during the probe trial. For data from isolated response trials, response inhibition theory is a possible cause of the negative priming found within the accuracy and RT data. However, an alternate theory is that the response associated with the distractor was not inhibited on the prime trial but this response may have been tagged in memory as a response that

should be avoided. If this memory episode were then retrieved at the time of the probe, this memory-based account would similarly predict response-based negative priming.

Although there appears to be a response based component, the effects found within the isolated temporal position trials indicate that the negative priming found must also reflect a time-based mechanism which cannot be explained by response-based mechanisms. Isolated temporal position trials contained sequences where the distractor from the prime trial and the target from the probe trial appeared in the same relative temporal position following the fixation point but required different numeric responses. These data show that participants were significantly slower and less accurate on the ignored repetition conditions than the control conditions, providing consistent and robust data in support of Kahan et al.'s (2017) initial findings of temporal negative priming. These data must also reflect some form of memory-based process like the type described by Neill and colleagues (Neill, Valdes, Terry, & Gorfein, 1992) because it makes very little sense for a person to inhibit a moment in time. Even if the moment the distractor is presented on the prime were inhibited, this temporal position is in the past by the time the target appears in the probe. As such, the data seem to indicate that participants store in memory that distractors are likely to appear at a certain moment in time following the fixation. In situations where this memory is retrieved on the probe trial, RTs are slowed when the target appears at that position.

Although Experiment 1 produced strong results in favor of temporal negative priming, some aspects of the data were unexpected. It was expected that trials where the response and temporal positioning of the stimuli were confounded would also yield negative priming. However, an analysis of these conditions did not find any indication of temporal negative priming and instead only indicate that participants were more accurate in the slow conditions

than fast conditions. Further research into the cause of these results will be required to bring clarity to this issue.

Similarly, the analysis of schizotypal personality traits and marijuana usage did not show the expected pattern of reduced negative priming for habitual users. Past research has indicated that individuals who are heavy marijuana users or have schizotypal personalities, depression, Alzheimer's disease or ADHD exhibit reduced negative priming (Albertella et al., 2016; Vaughan et al., 2006; Ungar et al., 2010; Macqueen et al., 2003; Ossmann & Mulligan, 2003; Frings et al., 2007). Considering marijuana use and schizotypal traits did not correlate with temporal negative priming these demographic questions were removed from Experiments 2 and 3.

Next Area of Research. This experiment is one of the first to examine temporal negative priming. To date, many theories have been put forward to explain the mechanisms that cause negative priming. Most of the theories behind negative priming attribute it to either inhibition or memory. For example, Tipper (1985) argued for an inhibition theory. He attributed the cause of negative priming to the inhibition of the distractor stimulus while the target is encoded during the prime trial. When a distractor from a prime trial is then subsequently used as a target in a probe trial, this inhibition creates a delay in RTs. This theory seems the least likely cause for temporal negative priming seeing as time is linear and the temporal position of the distractor stimulus from any prime trial cannot be exactly replicated and then inhibited in any probe trial because the temporal position itself has passed.

Memory-based theories of negative priming include episodic retrieval theory. Episodic retrieval theory argues that over time stimuli become tagged in memory as information to attend to or to ignore (Neill, 1997; Neill et al., 1992). When a distractor stimulus is then recalled in

subsequent trials, it is recalled as an item which should be ignored, and this is what causes the delayed response. This provides a possible explanation for the temporal negative priming found in this study. This study consistently utilized Xs as the target and Os as the distractor. This consistency between trials might encourage the X and O to automatically induce an association as either a target or distractor at a point in time following the fixation. When a target from a probe trial appears in the temporal location of the distractor from a prime trial, that memory recall of a distractor presented at that temporal position from the fixation point might be responsible for the delay on ignored repetition trials.

A further memory based theory of negative priming is stimulus-response binding theory. Stimulus-response binding theory is a variant of episodic retrieval theory that was proposed by Mayr and Buchner (2006) to explain identity-based negative priming. They argue that the memory retrieval individuals experience is the retrieval of the entire prime episode as a whole and it is this inappropriate recall of the prime response from the prime episode that causes negative priming during the probe. However, unlike identity negative priming, the stimuli in this experiment never changed (participants always attended Xs and Os in both the ignored repetition and control conditions) and participants were required to attend to both the target and distractor on each trial. Considering the target stimulus in both the prime and the probe sequences are Xs, according to stimulus-response binding theory participants would be recalling the entire prime sequence on every probe (i.e., both ignored repetition trials and control trials). This means that any instance in which the probe X and the prime X were not situated in the same temporal position in relation to the fixation point, a time-consuming conflict would occur because of the mismatch in responses. Therefore, we would expect to see these conflicts happening across a number of different trials including the control trials. For this reason, it is unlikely that stimulus-

response binding theory specifically could be a causal mechanism for temporal negative priming.

An alternate theory to inhibition or episodic retrieval theories of negative priming is feature mismatch theory, introduced by Park and Kanwisher (1994). These authors argue that it is a mismatch between the features that induces spatial negative priming. According to their theory, participants bind the features of a specific stimulus to a specific location determined by the prime trial. When a different target symbol is shown in the position of a distractor from the prime trial, this mismatching of features bound to the same location creates a time delay in responses. In our study, the target stimulus contained hard, straight lines, and our distractor stimulus had curved edges creating two very distinct featural shapes. Due to the significant differences in the features of our target and distractor stimuli, it is very possible that feature mismatch theory may be the causal mechanism behind temporal negative priming. Although this theory is not supported as being the causal mechanism of spatial negative priming for vision (Tipper, Weaver, & Milliken, 1995), empirical evidence has shown that this theory does explain it in auditory experiments (Mayr et al., 2011). Spatial and temporal negative priming do have a similarity in that in both situations it is the location (either spatial or temporal) of the prime distractor which interferes with the probe target. With feature mismatch theory standing as a possible causal mechanism for spatial negative priming in the auditory modality, it is possible that this could be the causal mechanism behind temporal negative priming as well.

At this time, the contributing mechanisms behind temporal negative priming are still unknown. The isolated response trials (i.e., those trials where the target on the probe requires the response associated with the distractor from the prime) could be accounted for by either response inhibition theory or memory recall. However, for the isolated temporal position trials, two

theories of negative priming (episodic retrieval and feature mismatch theory) stand as the most probable causes. Experiment 2 tests Park and Kanwisher's (1994) feature mismatch theory to determine if it is the dissimilarities between features of the target on the probe and features from the distractor on the prime that induces temporal negative priming. Their feature mismatch theory would predict that negative priming should only emerge when there is a feature mismatch; no negative priming should be found if there is no feature mismatch between the stimuli situated at the same temporal locations in the prime and the probe.

Experiment 2

To test Park and Kanwisher's (1994) feature-mismatch hypothesis, the color of the target and distractor varied from trial to trial, although all the stimuli remained the same. Doing this made it possible to have a distractor on a prime trial that is identical to the target on the probe trial (feature match) as well as a distractor on a prime trial that is different from the target on the probe trial (feature mismatch). If negative priming results from difficulty binding a target to a temporal position that was associated with different visual features, then temporal negative priming should only emerge on mismatch trials. The addition of matching versus mismatching as another independent variable to the design has the potential to decrease the number of critical trials per condition substantially, and for this reason trials where the effects of temporal positioning were confounded with effects of the response were removed. This made it possible to have the same number of critical trials per condition while keeping the overall length of this experiment comparable to Experiment 1.

Methods

Participants. The participants for this study were taken from the same introductory and intermediate psychology courses at Bates College as Experiment 1. Data were collected from 49 participants (32 females and 17 males) and none of them participated in Experiment 1. The participants ranged in age from 18 to 21 years with an average age of 19.

Procedure. The procedure of Experiment 2 closely followed that of Experiment 1 with the only major changes being to the stimuli. In total, Experiment 2 lasted 45 minutes. Just as in Experiment 1, participants were given a prime and probe trial pair. In both sequences, participants viewed four boxes flashing in the same place on the screen in rapid succession. In this experiment, both the target and the distractor stimuli were Xs of various colors. During the prime trial, participants were shown a colored letter at the beginning of the sequence (either a red **r**, a blue **b**, a green **g**, or an orange **o**) to indicate which of the two colored Xs was the target in the upcoming sequence. During the probe trial, participants were similarly shown a colored letter and then viewed four boxes flashing in the same location on the screen. Here, only one X appeared within the boxes and its color always corresponded to the letter seen at the beginning of the sequence. Mirroring Experiment 1, participants were asked to respond to the temporal position of the target (box 1, 2, 3, or 4) as fast as possible when a “?” appeared on the screen at the end of each sequence. Just as in Experiment 1, participants were asked “when was the distracting X?” randomly at the end of 88% of the trials. As accurately as possible, participants needed to indicate when the distractor had been shown on the prime. The last major change between this experiment and the last relates to the timing sequences. While the fast-slow and slow-fast timing sequences were once again used, the fast-fast and slow-slow sequences were

removed so that the same number of critical trials per condition could be shown while keeping the overall length of the experiment similar to Experiment 1.

Conditions. The same trial conditions from Experiment 1 were present in Experiment 2 with the exception of conditions of A-C. This left seven conditions of which F, H and J were critical for assessing temporal negative priming:

Varied timing (fast-slow vs slow-fast; see Figure 1):

- (D) Ignored Position + Attended Response
- (E) Attended Position + Ignored Response
- (F) Ignored Position (different response)
- (G) Attended Position (different response)
- (H) Ignored Response (different position)
- (I) Attended Response (different position)
- (J) Unrelated (including “position controls”)

Results

Isolated Temporal Analysis. All of the data are presented in Table 2. The RTs and accuracy data for probe sequences which focused solely on temporal position isolated from the effects of response were analyzed in a 2 (speed: fast-slow vs. slow-fast) x 2 (feature relation: match vs mismatch) x 2 (negative priming: ignored repetition vs control) repeated measures ANOVA. For all the analyses, only the RT data from trials in which participants correctly determined the target from the prime and probe sequences were analyzed and geometric mean values were used to reduce the influence of

Table 2. Mean Reaction Times (RT) and Proportion Errors (PE) in Experiment 2 along with 1 SEM.

Prime-Probe Relation	Temporal Sequence of Prime Trial								Marginal Means			
	Fast				Slow				RT	SEM	PE	SEM
	RT	SEM	PE	SEM	RT	SEM	PE	SEM				
Temporal Position Alone												
Ignored	431	34	.05	.01	420	30	.11	.02	426	28	.08	.01
Unrelated	451	55	.14	.03	399	36	.11	.02	425	37	.13	.02
Negative Priming	-20		-.09		21		.00		1		-.05	
Response Repetition Alone												
Ignored	390	25	.07	.02	418	34	.07	.01	404	25	.07	.01
Unrelated	378	25	.12	.02	399	28	.13	.02	389	25	.13	.02
Negative Priming	12		-.05		19		-.06		15		-.06	

outliers. Likewise, for the accuracy data only trials in which individuals correctly determined the target on the prime sequence were analyzed. A main effect of positive priming was found within the accuracy data, indicating that participants were more accurate at determining the probe in the ignored repetition ($M = .92$) condition than the control condition ($M = .87$), $F(1, 42) = 5.75$, $p = .021$. A significant interaction between speed and negative priming was also found, $F(1,42) = 4.67$, $p = .036$. Further analysis determined that participants were significantly more accurate on the ignored repetition trials ($M = .95$) than the control trials ($M = .86$) in the fast-slow prime-probe sequences, $t(44) = 3.41$, $p = .001$. There was no difference in accuracy between the ignored repetition and the control trials for slow-fast sequences ($p = .943$). No other significant results were found in the accuracy or the RTs of the isolated temporal position data.

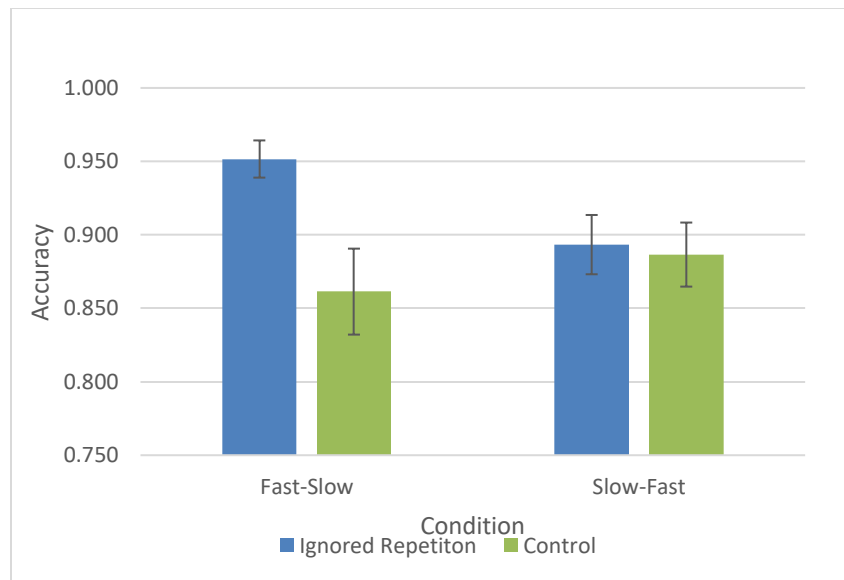


Figure 8: This figure indicates an interaction between speed and accuracy within the isolated temporal conditions (conditions F and J). While there is no difference in accuracy for the slow-fast trials, positive priming is found in the fast-slow trials. Error bars represent 1 SEM.

Isolated Response Analysis. RTs and accuracy for conditions that isolate response-level effects were likewise analyzed using the same 2 (speed) x 2 (feature relation) x 2 (negative priming) repeated measures ANOVA. Here too a significant main effect of positive priming was

found in the accuracy data, $F(1, 46) = 18.31, p < .001$. This revealed that participants were more accurate in the ignored repetition condition ($M = .93$) than in the control condition ($M = .87$). No other significant results were found.

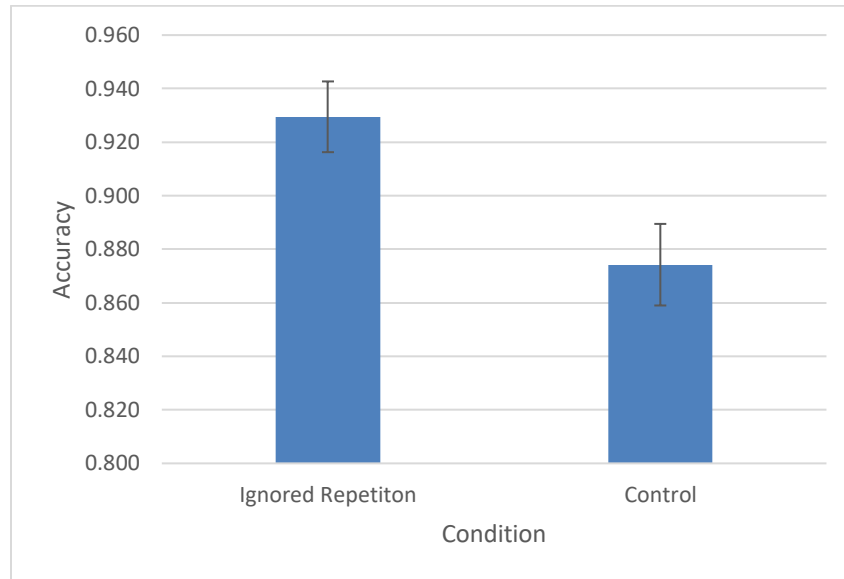


Figure 9: This figure depicts the positive priming found in the accuracy data in the isolated response trials (conditions H and J). Error bars represent 1 SEM.

Discussion

Summary of Results. The analysis of Experiment 2 provided a number of surprising results. First, the RT data did not yield significant effects. More surprisingly, the accuracy data in both the temporal position and response-based analyses indicated that participants experienced positive rather than negative priming. More specifically, participants responded more accurately to the temporal position of a target on the probe trial when a distractor appeared at that same temporal position on the prime trial relative to situations where the prime trial was unrelated to the probe (during slow probe presentations only). The data also indicate that participants responded more accurately when the response needed on the probe trial matched the response required for the distractor on the prime trial. The lack of negative priming indicates that if feature

mismatch theory is the causal mechanism, then a color mismatch between the prime and probe is not sufficient to produce negative priming. However, Park and Kanwisher's (1994) feature mismatch theory cannot be entirely ruled out based on these data. Park and Kanwisher (1994) argue that negative priming is due to variations in the symbol identities which are bound to specific locations. While they suggest that it is the symbol's identity that causes the time delay, they state that it is unclear whether the mismatch must be related to the target and distractor's identity, shape, or some more abstract category. As such, if a mismatch in low-level perceptual features (like color) is not sufficient to cause a slowdown then the prime and probe trials may have been characterized as matching, resulting in positive priming.

In this study, the only variation between the target and distractor was the color, but the identity and the shape did not differ between trials. Facilitation was found in the isolated response data and in the fast-slow prime-probe trials in the temporal data. These results indicate that the distractor stimulus that was used here did not create the expected time delays or errors associated with negative priming. According to Park and Kanwisher's (1994) research, when a spatial location was occupied with matching symbols regardless of whether they were a target or distractor, facilitation was found as opposed to the expected negative priming described in other theories. Further evidence of this is found in a study conducted by Mayr, Hauke, and Buchner (2009) on the presence of feature mismatch theory in the auditory modality. Their study concluded that feature mismatch theory is the causal mechanism responsible for spatial auditory negative priming. In their study, they utilized two different sounds (a crow and a piano) for their target and distractor stimuli. These two noises are not only distinct sounding from each other but also come from entirely different sources: one being an animal and one being an inanimate object, which could be a factor in why negative priming was found in their study. The lack of

change in the meaning or shape of our stimuli may account for the positive priming which was found. Based upon the data collected in this experiment, if feature-mismatch is responsible for temporal negative priming then the mismatch cannot be based on a simple featural change, but instead the mismatching may be dependent on the meaning or shape of the stimuli. Further research that manipulates the shape and/or meaning of the target and distractor is needed in order to test these possibilities.

At this time, it remains unclear if feature-mismatch contributes to temporal negative priming. This experiment indicates that if feature-mismatch does play a role then a more significant change must be made to the stimulus than just the color. As such, feature mismatch theory cannot be entirely ruled out. In addition, if temporal negative priming does depend on the mismatch of features between the target on the probe and the distractor on the prime this mismatch is most likely identified in a retrospective manner. According to Park and Kanwisher (1994) spatial-negative priming arises because participants have a difficult time binding features to a location in space where a distractor had previously been bound. However, the same cannot be true of temporal positions since the temporal positioning of the distractor on the prime trial is in the past when the target on the probe appears (i.e., the two occupy different temporal positions, even though they are occupying the same temporal position in relation to the fixation point). For this reason, if a mismatch of features does play a role it must be a retrospective memory of having seen a different (mismatching) stimulus at the same relative point in time that is responsible for temporal negative priming.

However, just as this memory-based version of feature mismatch theory cannot be ruled out, other theories of negative priming must also be considered. Episodic retrieval still stands as a possible explanation for temporal negative priming. Episodic retrieval is based on the idea that

the target on the probe trial cues the retrieval of the prime episode and if that memory contains a tag that the stimulus is something to be ignored, negative priming will be found because of the incongruence of having to react to a target that is tagged as something to ignore (Neill, 1997). Based upon episodic retrieval, each stimulus is coded as either an attended item or an ignored item. For the present experiment, although the color of the target differed on a trial-by-trial basis, the one consistency between all of the stimuli was their shape. This means that for every trial pair, participants were coding two Xs as targets to every one X as a distractor. According to episodic retrieval theory, this repetitive tagging of an X as a target would result in many episodic memory traces where an X is tagged as a target that needs to be attended and responded to (Neill, 1997). Therefore, with each passing trial, participants would be twice as likely to tag the X as a target rather than a distractor. Since the colors of the target and distractor varied on a trial-by-trial basis, it would not be the color of the stimulus that would elicit retrieval. Instead, the identity of the stimulus would likely be the cue for retrieval as well as the information that is tagged in memory. Considering positive temporal priming was found during fast-slow prime-probe trials, it is possible that participants were relying on the automatic episodic memory retrieval to help make speeded responses. During the fast-slow trials, each box was only present on the screen for 250 ms with 250 ms blank spaces on the prime. This rate may have been too fast for participants to accurately bind the correct color with the correct temporal location. Without this proper binding during the prime trial, the participant's responses may have been aided by their associations from previous trials. With consistent reinforcement that an X is more often than not presented as a target, it would stand to reason that individuals would retrieve from memory that an X was a target rather than a distractor. This might explain why positive priming rather than negative priming was found.

An alternative explanation of these results may be due to difficulties individuals had with the design of the experiment itself. Just as in Experiment 1, participants were asked to recall the location of the distractor stimulus. This required that participants remembered the location of three stimuli which only differed in their color but did not differ in their inherent meanings or shape. This increase in cognitive load may have impaired a person's ability to properly bind the target and distractor locations with the correct X during the prime trial, and if they were all tagged as positions with an X this may have produced facilitation on the probe trial. This could suggest design flaws with the experimental setup. Possible directions for future research would be to replicate this experiment with varying symbols to help distinguish between the target and the distractor, remove the distractor recall task at the end of each trial, or slow down each sequence as a whole.

Next Area of Research. To date temporal negative priming has only been obtained in the visual modality, just as the majority of negative priming research has been done in the visual domain. However, more recent studies have looked into representations of negative priming in other senses such as tactile senses (Frings, Mast et al., 2014) and auditory senses (Mayr & Buchner, 2007). Negative priming in the auditory modality began with a study by Banks, Roberts, and Ciranni (1995) who utilized auditory shadowing in three experiments to exhibit a negative priming effect. In their experiments, participants were cued to attend to either a specified location (the left or right ear) or a specified voice (female or male) and repeat the target phrase. The duration of these negative priming effects was also assessed. The results of all of their experiments successfully showed negative priming when individuals shadowed speech, thereby extending negative priming research to the auditory domain. Since this finding, various other studies utilizing different auditory clips such as animal noises (Mayr et al., 2011), musical

notes (Buchner & Steffens, 2001) and synthetic noises (Mondor, Leboe, & Leboe, 2005) have all shown that participants were worse to identify a probe target when it had previously been ignored as a prime distractor (Frings, Schneider, & Moeller, 2014). This evidence has successfully proven that auditory negative priming exists in many forms and is consistent across different categories of auditory stimuli.

Identity-based negative priming clearly extends from the visual to the auditory domain (Banks et al., 1995; Buchner & Steffens, 2001; Mayr & Buchner, 2006). In a study introduced by Buchner and Steffens (2001), participants listened to two different instrument sounds, one played in each ear. Individuals first heard a click in the target ear and then were asked to identify the musical tone they heard in the attended ear as either a wind or string instrument. Following typical negative priming procedure, participants were exposed to both a prime and probe trial and results again found a hindrance in RTs and accuracy for the probe target when it had previously been used as a prime distractor. Similar studies, such as that of Mondor et al. (2005), utilized an identification task of synthetic noises to produce similar results. This demonstrates that identity-based negative priming is not limited to the visual domain.

In addition to identity-based negative priming, spatial negative priming extends to the auditory domain as well (e.g., Mayr et al., 2011). For example, in Mayr et al.'s (2011) first experiment, participants were situated in the middle of four speakers placed in different locations around them. Participants were cued to listen for a specific animal noise by viewing an image of that animal on a screen before the trial. So for example, if participants were to attend to a lamb "baa-ing" they would view a lamb on the screen in front of them. During the trial, participants would hear the target sound and a distractor sound, each played in their own individual speaker location. They would then respond from which speaker they heard the target sound coming. This

research found evidence of spatial negative priming while also finding evidence that spatial negative priming with auditory stimuli is nicely explained by Park and Kanwisher's (1994) feature mismatch hypothesis considering negative priming was only found when there was a mismatching between the stimuli at the same speaker. Although the causal mechanisms behind spatial negative priming in the visual domain is contested, Mayr et al.'s (2011) study suggests spatial negative priming for auditory stimuli requires a feature mismatch. This study also is one of many that shows spatial negative priming replicates across modalities (Mayr et al., 2009; Mayr, Moller, & Buchner, 2014; Moller, Mayr, & Buchner, 2015; Moller, Mayr, & Buchner, 2016).

Although fewer studies have examined auditory negative priming compared to visual, two major findings have emerged when comparing these different sense domains. The first, which was just described, is that negative priming tends to manifest in the same ways and generally follow the same principles in both modalities (Mayr & Buchner, 2007; Frings, Schneider et al., 2014). The only exception here being that the mechanism behind spatial auditory negative priming was determined to be caused by feature mismatch theory, whereas spatial negative priming in the visual domain does not appear to depend on feature mismatch (Mayr et al., 2009). The second finding is that negative priming effects appear to be consistently larger in the auditory relative to the visual domain (Mayr & Buchner, 2007; Frings, Schneider et al., 2014). In the initial research conducted by Banks et al. (1995), this difference in negative priming was attributed to the various processing types which account for vision and hearing. They argue that since visual fixation is supplemented by visual acuity, the processing time for visual stimuli is shorter and requires less energy directed at central processing. Focusing attention on auditory information does not benefit from ear movement in the same way that visual processing benefits

from eye movements, meaning that auditory selection requires more central processing and for this reason takes longer. These differences in internal processing contribute to slower RTs for auditory negative priming tasks compared with visual tasks, creating what appears to be an enhanced negative priming effect in the auditory domain as opposed to the visual domain. The purpose of Experiment 3 was to explore whether temporal negative priming generalizes to the auditory modality.

Historically, standard auditory negative priming tasks have been conducted with two or more sounds playing simultaneously. It is the participant's responsibility to parse out either what the sound was or from where it originated (Mayr & Buchner, 2007). Experiment 3 changes this standard methodology. Here auditory negative priming is tested by presenting target and distractor stimuli in a linear and temporal manner (as was done in Experiment 1) as opposed to presenting the target and distractor simultaneously. To our knowledge, no one has investigated whether negative priming can emerge when sounds are played temporally. Based upon the reviews of the negative priming literature of Frings, Schneider et al. (2014) and Mayr and Buchner (2007), it is clear that negative priming in the visual domain also generalizes to the auditory domain. Likewise, comparative analysis indicates that these negative priming effects appear larger in the auditory domain than in the visual domain. Temporal negative priming in the visual modality was first reported by Kahan et al. (2017) and has now been replicated in the current Experiment 1. As such it is hypothesized that temporal negative priming will be found in the auditory domain as well.

Experiment 3

Methods

Participants. The participants for this study were taken from the same introductory and intermediate psychology courses at Bates College as the previous experiments. Data were collected for 38 participants in exchange for extra credit in their courses. Only individuals who had not participated in Experiments 1 or 2 were eligible to participate. This eliminated data from two participants who in fact had participated in an earlier study. Of these 36 participants, 21 self-identified as female and 15 self-identified as male. The participants ranged in age from 18 to 22 years old with an average age of 19.

Procedure. Experiment 3 employed the same methodology as Experiment 1 with the exception that auditory rather than visual stimuli were used. During the instructions section of the experiment, participants were told to put on headphones and listen to sample sounds and sequences before beginning the practice trials. All sounds lasted 250 ms to match the length of the presentation of visual stimuli from Experiment 1. The target sound was a high pitch bird chirping noise. The distractor sound was a lower pitch dog barking sound and the temporal locations which did not contain a target or distractor were signified by a neutral computer tone. The same fast and slow timing sequences and the same 11 conditions (A through J; see Figure 1) were presented in this experiment. To begin each prime and probe sequence, participants viewed a visual fixation point in the center of the computer monitor for one second. Participants then viewed a blank white screen while the sounds were played. Each prime sequence was composed of one bird sound (target), one dog sound (distractor), and two computer tones (neutral place holder). Similarly, each probe sequence was composed of one bird sound (target) and three computer tones (neutral place holders). At the end of each sequence a visual “?” appeared in the center of the computer monitor (as was the case in Experiments 1 and 2). When participants saw

the “?”, they answered as quickly as possible when they heard the target tone (either tone 1, 2, 3, or 4). In an identical manner to Experiment 1, after 88% of the prime-probe trial pairs, participants were asked to recall when they heard the dog barking from the prime sequence (either tone 1, 2, 3, or 4). On the remaining 12% of trials, participants were just asked to move on. In total, this experiment lasted 45 minutes.

Results

Confounded Trials. All of the data are presented in Table 3. For all analyses of RTs, only trials in which participants correctly localized the temporal position of the target on both the prime and probe trials were analyzed and geometric means were utilized to reduce the effects of outliers. For accuracy rates, only trials in which participants correctly localized the temporal position of the target on the prime sequence were analyzed. One participant was removed because their overall accuracy was far below all other participants (having fewer than half of the trials correct in several critical conditions and no correct trials in other critical conditions). The data from the time sequences where temporal positioning was confounded with the response (conditions B and C), were analyzed in a 2 (speed: fast-fast vs. slow-slow) x 2 (negative priming: ignored repetition vs. control) repeated measures ANOVA. A significant main effect of speed was found indicating that participants were slower to respond during fast-fast sequences ($M = 475$ ms) than slow-slow sequences ($M = 438$ ms), $F(1, 34) = 5.91, p = .020$.

Table 3. Mean Reaction Times (RT) and Proportion Errors (PE) in Experiment 3 along with 1 SEM.

Prime-Probe Relation	Temporal Sequence of Prime Trial								Marginal Means			
	Fast				Slow				RT	SEM	PE	SEM
	RT	SEM	PE	SEM	RT	SEM	PE	SEM				
Temporal Position and Response Repetition												
Ignored	494	38	.05	.02	452	30	.01	.01	473	32	.03	.01
Unrelated	456	35	.07	.03	425	29	.04	.01	440	31	.06	.02
Negative Priming	38		-.02		27		-.03		33		-.03	
Temporal Position Alone												
Ignored	470	33	.06	.03	526	49	.10	.03	498	36	.08	.03
Unrelated	489	34	.03	.01	435	34	.05	.02	462	31	.04	.01
Negative Priming	-19		.03		91		.05		36		.04	
Response Repetition Alone												
Ignored	416	26	.03	.01	499	47	.11	.03	457	35	.07	.02
Unrelated	420	28	.03	.01	477	39	.05	.01	448	33	.04	.01
Negative Priming	-4		.00		22		.06		9		.03	

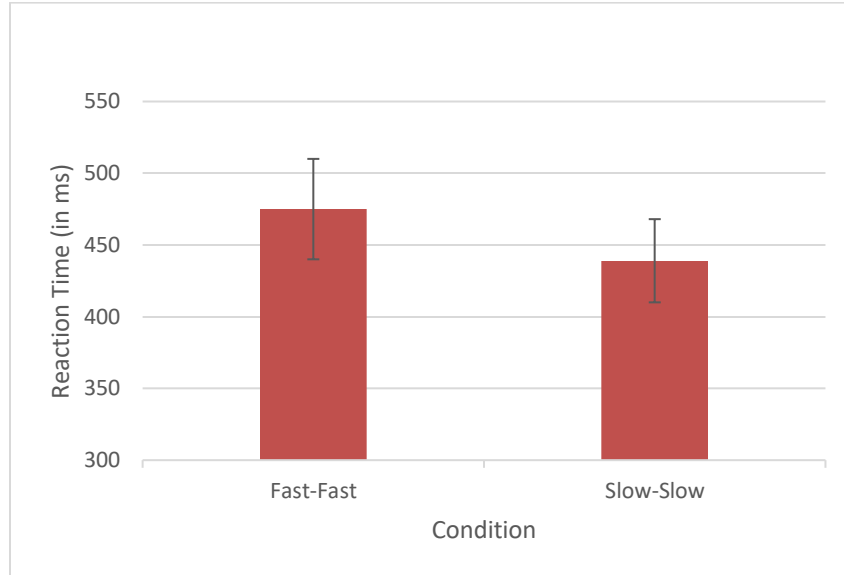


Figure 10: This figure depicts a main effect of speed (in ms) found in the confounded conditions (conditions B and C). Here, participants were 37 ms slower to respond in the fast-fast trials than the slow-slow trials. Error bars represent 1 SEM.

There was also a significant main effect found for negative priming, $F(1, 34) = 6.58, p = .015$.

This indicates that participants were significantly slower to respond in the ignored repetition conditions ($M = 473$) than the control conditions ($M = 440$).

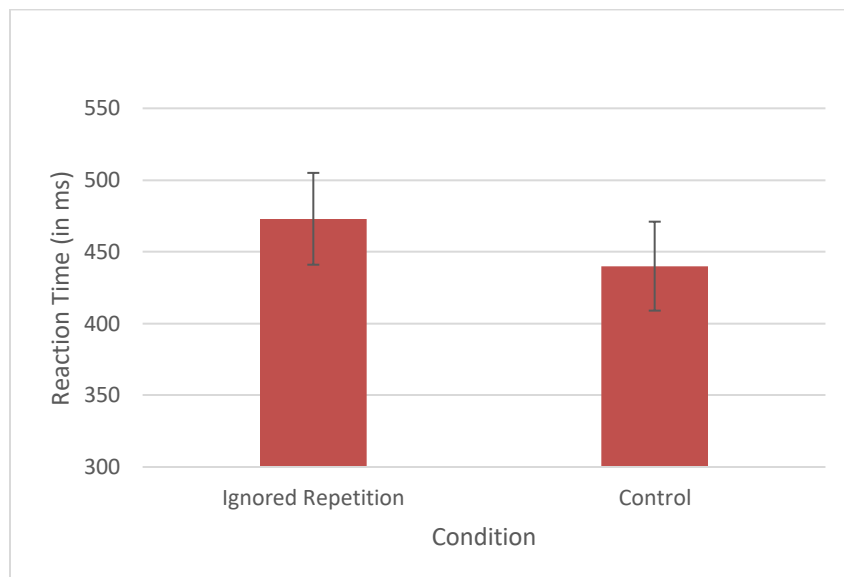


Figure 11: This figure indicates the main effect of negative priming found with the RTs for the ignored repetition trials and the control trials in the confounded conditions (conditions B and C). Participants were 33 ms slower to respond in the ignored repetition conditions than the control conditions. Error bars represent 1 SEM.

No significant results were found in the accuracy data though an inspection of the means suggest a hint of speed-accuracy tradeoff with somewhat more accurate performance on ignored repetition trials ($M = .97$) relative to control trials ($M = .94$).

Isolated Temporal Analysis. The RT and accuracy data for prime and probe sequences which focused solely on ignored repetition isolated from the effects of response were analyzed in the same 2 (speed: fast-slow vs. slow-fast) x 2 (negative priming: ignored repetition vs. control) repeated measures ANOVA. A significant interaction between speed and negative priming was found in the RT data, $F(1,34) = 5.79, p = .022$. A paired samples t-test determined that participants were significantly slower to respond in the ignored repetition conditions ($M = 526$ ms) than in the control conditions ($M = 435$) in slow-prime, fast-probe sequences, $t(34) = 2.46, p = 0.019$. No negative priming was found in the fast-prime, slow-probe sequences ($p = .492$). No other significant results were found within the RT or accuracy data.

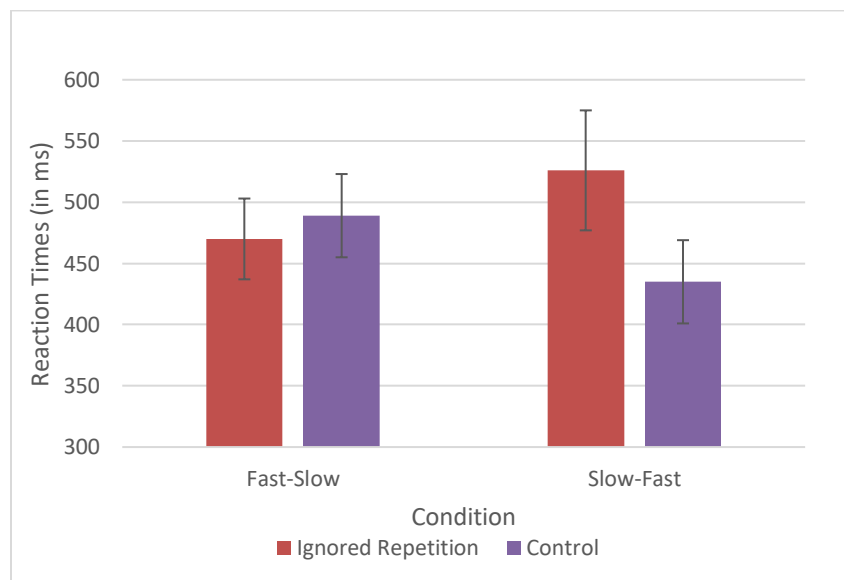


Figure 12: This figure depicts the significant interaction found between speed and negative priming. In the slow-fast conditions, participants were 91 ms slower to respond in the ignored repetition conditions than the control. Error bars represent 1 SEM.

Isolated Response Analysis. The RTs and accuracy data for prime and probe sequences which focused solely on responses isolated from the effects of temporal position were analyzed in the same 2x2 repeated measures ANOVA. A significant main effect for speed was found in the RT data, indicating that participants were faster to respond when the probe sequence was slow ($M = 417$ ms) than when the probe sequence was fast ($M = 488$ ms), $F(1, 34) = 11.59$, $p = .002$.

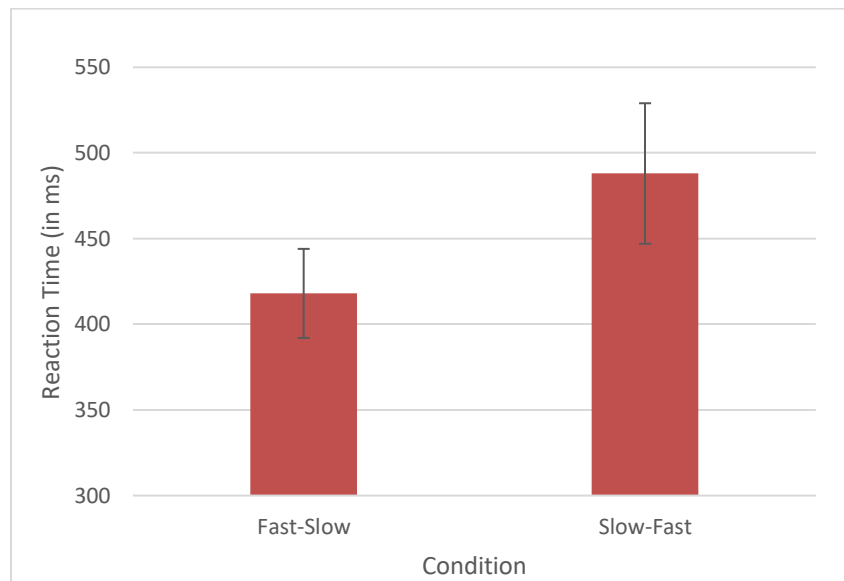


Figure 13: This figure indicates the significant main effect found for speed in the RTs (in ms) of the isolated response trials (conditions H and J). Participants were 71 ms slower to respond in the slow-fast trials than the fast-slow. Error bars represent 1 SEM.

No other effects reached significance in the RT data. For accuracy rates, there were two significant main effects and a significant interaction. The main effect of speed showed that participants were significantly more accurate on fast-slow trials ($M = .97$) than in slow-fast trials ($M = .92$), $F(1,34) = 8.95$, $p = .005$. The main effect of negative priming indicates that participants were more accurate on the control trials ($M = .96$) than ignored repetition trials ($M =$

.93), $F(1, 34) = 6.72, p = .014$. Finally, there was a significant interaction between speed and negative priming, $F(1,34) = 4.52, p = .041$. Paired samples follow up t-tests determined that individuals were significantly more accurate in the control condition ($M = .95$) than in the ignored repetition condition ($M = .89$), $t(34) = -2.59, p = .014$ during slow-fast sequences. No negative priming was found in the accuracy rates during fast-slow sequences ($p = .652$).

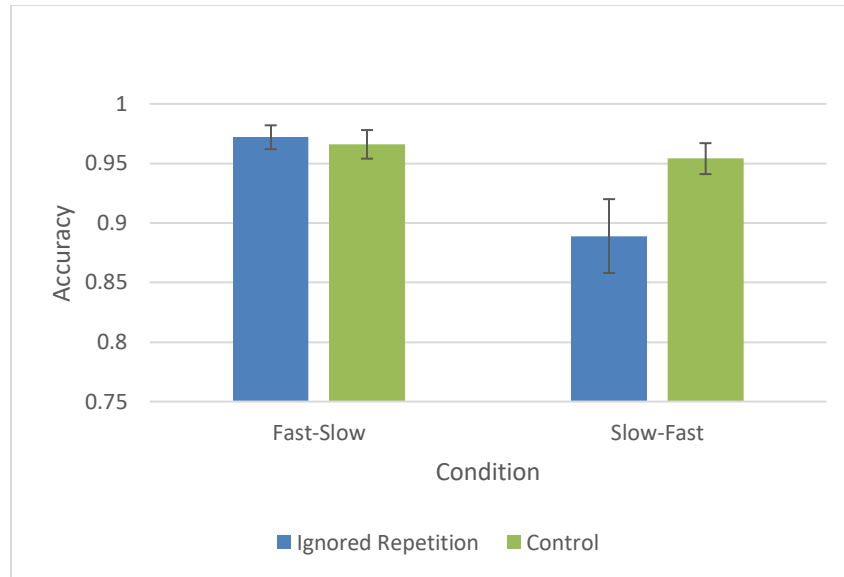


Figure 14: This figure depicts an interaction between speed and negative priming in the accuracy data for the isolated response conditions (conditions H and J). Although participants did not vary in their accuracy in the fast-slow sequences, participants were significantly less accurate in the ignored repetition trials than the control trials in the slow-fast sequences. Error bars represent 1 SEM.

Discussion

Summary of Results. The results of Experiment 3 successfully showed that temporal negative priming generalizes to the auditory modality. Data from conditions where temporal positioning is confounded with responses (conditions B and C) show two interesting results. First, there is significant temporal negative priming as evidenced by the fact that participants are slower to react on ignored repetition trials than control trials (though this effect may be partially influenced by a speed-accuracy tradeoff). Second, participants are faster to respond on probe trials in slow-slow prime-probe sequences than fast-fast prime-probe sequences. With fewer

variables to recall and more time to process during the slow probe sequences, participants were likely prepared to answer quickly and confidently when the question mark appeared at the end of the sequence. However, the fast-fast trials may have been too quick for participants to fully process the temporal locations of the targets before the question mark appeared, creating a delay in processing on those trials. Therefore, because temporal positioning and responses are confounded in these sequences, these data do not indicate whether temporal negative priming in the auditory modality reflects temporal positioning or response-based mechanisms.

An analysis of the isolated temporal position trials found a robust temporal negative priming effect in RTs. Further analysis found that this temporal negative priming was speed dependent and only appeared in slow-fast prime-probe sequences. Specifically, participants were just over 90 ms slower to respond in the ignored repetition conditions than control conditions. However, an analysis of the temporal negative priming found in Experiments 1 and 3 did not indicate that there was a larger effect in the auditory domain compared to the visual domain, as predicted by other comparative reports of negative priming in these two modalities (Banks et al., 1995; Mayr & Buchner, 2007; Frings, Schneider et al., 2014). Since temporal negative priming only appeared in the slow-fast trials, it is possible that during fast-slow trials (where temporal negative priming is not found) the speed of the prime trial did not provide participants enough time to bind or tag the temporal positions as positions which should be ignored. The central aspect of negative priming is that a delay occurs in responding to the probe target when that stimulus or location had previously been used as or contained a distractor during the prime trial. In order for this delay to occur, participants must be able to bind the correct stimulus to the correct temporal position during the prime. It is possible that since the prime had two different stimuli which needed binding, the fast sequence occurred too rapidly for participants to properly

bind each stimulus (target and distractor) to the correct temporal position. Without tagging a specific point in time as containing a distractor on the prime trial, there would not be a time delay if a target appears at that temporal position on the probe trial. Conversely, the slow prime trial may provide enough processing time for participants to properly bind each stimulus (target and distractor) to a temporal position, which is possibly why we only see temporal negative priming in the slow-fast trials. A future area of research would be to explore how slowing down each sequence as a whole impacts the pattern of temporal negative priming that is found.

Temporal negative priming in the auditory modality also reflects a response-based mechanism as evidenced in the accuracy data. Robust response-based negative priming within the accuracy data was similar to the temporal positioning data in that this too only appeared during slow-fast prime-probe trials. This also may have occurred if it was difficult to associate specific responses with a distractor during fast prime sequences. If these trials appeared too quickly, they may have prevented appropriate binding during the prime. Once again, future research could investigate how slowing down the sequences as a whole influences the pattern of temporal negative priming. The RT and accuracy data also indicate that participants performed better (faster and more accurately) on the fast-slow prime-probe trials than slow-fast prime-probe trials. Considering these analyses focus on accuracy and RT on the probe trial, it would stand to reason that a slower probe presentation rate would allow participants more time to process the sequence of sounds. This increased processing time might facilitate responses and improve accuracy.

In review, the results of Experiment 3 indicate that temporal negative priming generalizes to the auditory modality and this negative priming effect has both a time-based and response-based component. The results from this experiment follow a similar pattern to those found in

Experiment 1, supporting previous findings that negative priming occurs across modalities (Banks et al., 1995; Mayr & Buchner, 2007; Frings, Schneider et al., 2014). Based on comparisons of visual and auditory negative priming, the mechanism(s) responsible for producing negative priming in one modality are likely to be the same mechanism(s) in the other modality. As is the case in Experiment 1, it seems likely that the mechanism responsible for temporal negative priming in the auditory modality is memory based as opposed to inhibition of a point in time. Just as in Experiment 1, it is improbable that theories of inhibition describe temporal negative priming because it is unlikely that participants would form a mental representation of point in time and then inhibit this representation, especially when that point in time had already passed.

Memory-based theories, such as episodic retrieval theory, which have been described for visual temporal negative priming are more likely candidates for explaining auditory temporal negative priming. According to the episodic retrieval theory, it is recall of a tagged memory which causes negative priming (Neill et al., 1992; Neill, 1997). If the temporal location from the prime trial had previously contained a distractor, participants would experience negative priming as a function of having to now respond to a temporal position that was previously tagged as a position to ignore.

Although memory-based mechanisms could be responsible for temporal negative priming, feature mismatch theory must also be considered (Park & Kanwisher, 1994). As previously described, feature mismatch theory may be the causal mechanism behind auditory spatial negative priming (Mayr et al., 2009) but this does not appear to be the cause of visual spatial negative priming (Tipper et al., 1995). In this study, the sounds which were used for our target and distractor were both distinct sounding and came from semantically different sources (a

dog and a bird). This means that on the ignored repetition conditions, the distractor in one temporal position on the prime trial sounded distinctly different and had a different semantic meaning than the target played in relatively the same temporal position on the probe. Since the two sounds occupy different points in time, it must not be the case that people have difficulty binding sounds to a point in time that had mismatching features (since the prime is in the past). However, it could be the case that people remember having bound different features to a relative point in time, and this memory-based mismatch of features contributes to negative priming. Indeed, Mayr et al. (2009) used stimuli that were quite distinct both in sound and in meaning (a piano or a crow). Which of these sounds was the target and which was the distractor could either remain the same or change between the prime and probe trials. It was found that negative priming only occurred on trials where the sound at a specific location changed. However, negative priming was not found when the sound at that location remained the same. For example, if the piano sound was played in the same location during both sequences and was the target during the probe sequence but was the distractor in the prime, negative priming was not found. On the other hand, if a crow sound was the distractor during the prime and the piano was the target in the same location on the probe, negative priming was found. Auditory temporal negative priming may very well be caused by the mismatching of tones at specific temporal positions and this awaits further testing.

Just as in Experiment 1, response-based temporal negative priming was found. This negative priming could be attributed to two possible mechanisms. From a response inhibition perspective, the inhibited response associated with the distractor on the prime trial would lead to a response delay if the probe target required the same response that was just inhibited (Buckolz et al., 2012). So, for example, if the dog barking during the prime appeared as the third tone, a

response to the bird chirping during the probe trial would be inhibited if it too was the third tone (irrespective of whether the two occupy the same relative temporal positioning).

In summation, patterns of temporal negative priming were found in the auditory modality and the results of this study were in accordance with those results found in Experiment 1. Just as in Experiment 1, temporal negative priming reflects both time-based and response-based components. Although various mechanisms may contribute to this effect, further research is necessary to determine which mechanisms cause temporal negative priming.

General Discussion

Summary of results

The results of Experiment 1 provide robust evidence for the presence of temporal negative priming, confirming the findings of Kahan et al. (2017). The results of Experiment 2, although inconclusive, show that temporal negative priming is affected by manipulations that alter the distractor, yet the reason for this awaits further scrutiny. The results of Experiment 3 indicate that temporal negative priming extends to the auditory domain. Both Experiments 1 and 3 found temporal negative priming within the isolated temporal trials and the isolated response trials. Although there is a response-based aspect to temporal negative priming, the negative priming found within the temporal conditions indicates that there is a time-based component as well. These data indicate that people can store in memory and retrieve information about the relative temporal positions of events and that processing of this sort is affected by recently experienced temporal episodes.

Together Experiments 1 and 3 show several interesting trends. In these two experiments, temporal negative priming was found to have both an isolated temporal aspect and an isolated response aspect. These results indicate that there must be multiple mechanisms which cause

temporal negative priming. Although a response-based mechanism must contribute to temporal negative priming, these results also indicate that participants are able to bind a stimulus to a specific temporal position within each sequence. Not only are individuals able to process stimuli within segments of time, but they must also be able to make comparisons between these past and present time sequences.

Similar to the findings in Kahan et al. (2017), Experiments 1 and 3 also show a relationship between temporal negative priming and the speed of the sequences. Just as in Kahan et al. (2017), both Experiments 1 and 3 indicate that negative priming was stronger during slow prime than fast prime presentations. Although the interaction between timing and negative priming was not significant in Experiment 1, the numerical trend was such that individuals experienced stronger negative priming during the slow-fast than the fast-slow trials. Experiment 3, however, did find a significant interaction between speed and temporal negative priming. In this experiment, temporal negative priming only appeared on trials with a slow-fast sequence. These findings may signify that some critical amount of time may be needed to properly bind the target and distractor to a temporal location. This may be due to the complexity of having to bind two stimuli (the target and the distractor) during the prime sequence as opposed to binding only one stimulus on the probe trial. However, without further research this remains to be seen. An interesting direction for future research would be to explore whether temporal negative priming emerges in both the fast-slow and slow-fast prime-probe presentations if the sequences were collectively slowed down.

The results of Experiment 2 were less conclusive than those of Experiments 1 and 3. The first interesting finding is that the positive priming found within the isolated temporal accuracy data was only found in the fast-slow prime-probe trials, which is the opposite finding of the

speed relationships found in our other experiments. At this time, it is not clear why positive priming was only found in the fast-slow trials and further research is required to understand this interaction. The findings from Experiment 2 also indicated that the mismatching feature between the prime distractor and probe target may need to be greater than just a change in color. If feature mismatch theory were to be the causal mechanism behind temporal negative priming, the mismatching between the prime distractor and the target probe must either change on a semantic or structural level. Also, the theory itself would have to be adjusted to account for the differences between the temporal locations of the prime and the probe. Considering the prime distractor occupies its own unique temporal position, what must cause the interference on the probe sequence would be a comparison between the recalled memory of that unique temporal position of the distractor on the prime and the current position occupied by the probe target. Although the results of this experiment did not provide conclusive evidence in favor of (or against) feature mismatch theory, it likewise did not rule out episodic retrieval as a possible explanation for these data. Perhaps the target on the probe needs to be from a different semantic set as the distractor on the prime for negative priming to emerge. Alternatively, the target on the prime may need to be associated with memory tags as something to ignore, causing the time delay and increase in errors.

The results of Experiment 1 and 3 are in full support of the original findings of Kahan et al. (2017), yet it is important to highlight the differences in methodology between the experiments reported here and that of Kahan et al. (2017). The initial findings of Kahan et al. (2017) were not always significant in both RTs and accuracy rates. This inconsistency was attributed to the possibility that participants were not fully encoding the temporal location of the distractor when it appeared after the target on the prime trial. Without encoding both the target

and distractor, the effects of temporal negative priming would diminish. In an attempt to remedy that issue, this study employed a similar methodology to that of Kahan et al. (2002) and MacDonald et al. (1999) by requiring participants to recall the location of the distractor on the prime trial after most sequences. This ensured that participants were attending to the distractor. Robust temporal negative priming was found in both the reaction times and the accuracy data of Experiment 1 when this method was used. Likewise, temporal negative priming was also found in Experiment 3 utilizing this method.

As such, this methodology may prove useful going forward for testing theories of temporal negative priming. However, it is acknowledged that this method does not always ensure an increase in negative priming. For example, in a study conducted by Joordens et al. (2006), attending to both the distractor as well as the target did not yield significantly more negative priming than conditions where participants only attended to the target (although it did yield numerically larger negative priming from 19 ms to 36 ms in the attended distractor experiments). In the ignored distractor cases, participants were required to decide if the target digit (written in red) was greater than or equal to 5, or less than or equal to 4 while ignoring white digits. In the attended distractor cases, participants were completing the same task for the red digits while also determining if the white distractor digits were in the shape of a number 9 or a letter p. Although Joordens et al.'s (2006) study did not yield the anticipated increase in negative priming, the data from this thesis are consistent with a recommendation that this methodology be used to produce the most consistent and robust results (at least until a superior method is found).

Limitations of this study

There are certain limitations to this study which are often present in psychology studies and should be addressed in future research. The participants of this study exhibit WEIRD

characteristics (Henrich, Heine, & Norenzayan, 2010). WEIRD populations are compiled of individuals who are predominantly Western, Educated, Industrialized, Rich, and Democratic and also make up the vast majority of the participants in behavioral and psychological research today. With the current tuition fees at Bates College listed at just over \$71,000 and only 22% of individuals identifying as students of color, the student body at Bates College is predominantly white and affluent (Bates Admissions, 2018; Bates Student Financial Services, 2018). Although we do not have direct data on the race or ethnicity of the participants in Experiments 1-3, the individuals who participated in these studies were reflective of the racial and ethnic make-up of the student body at Bates College. Similarly, participants in this study ranged between 17 and 22 years of age with an average age of 19, which is a very limited range. An important area of future research would be to extend this study into a wider range of age, socioeconomic, and racial groups to increase the generalizability of the results. Indeed, what makes negative priming research so interesting is findings that indicate that this result does not always generalize to different groups. Expanding psychological research to populations outside of colleges and universities is a crucial step toward gaining a better understanding of attention and cognition.

Future Areas of Research

The research presented here is the initial stage of new and exciting research into temporal negative priming. Future areas of research might explore the mechanisms behind this effect in both the visual and auditory domain. For example, to determine whether this effect is dependent on memory-based mechanisms it would be important to explore whether context can influence negative priming. It would also be useful to explore how different populations exhibit temporal negative priming.

The first direction of future research would be to determine the various causal mechanisms behind temporal negative priming. As previously outlined (see the discussions of Experiments 1-3), theories of inhibition such as those first described by Tipper (1985) are unlikely to be the cause of temporal negative priming as it is unreasonable to expect an individual to encode a point in time only to immediately inhibit this moment (with the only possible exception being response inhibition theory for response-based negative priming). Likewise, it is unlikely that inhibition from the prime trial causes the delay in the probe trial because even if the distractor on the prime was inhibited, the aspect which would be inhibited is a temporal position which had passed and cannot be replicated in the probe. This logic leaves only memory-based theories as possible mechanisms of temporal negative priming. As outlined in the discussions of Experiments 1-3, episodic retrieval theory or a memory variation of feature mismatch theory, and response-based inhibition could each contribute to temporal negative priming.

If future studies were to manipulate context, this would help determine if temporal negative priming is caused by a memory-based mechanism and this could be explored in the visual and auditory domain. Research has indicated that memory recall is better when individuals are tested in the same environment or same context in which they initially learn the information (Godden & Baddeley, 1975; Stefanucci, O'Hargan, & Proffitt, 2007; Im, Bedard, & Song, 2016). One well-known example of this is the contextual study conducted by Godden and Baddeley (1975), which had several university dive students either learn a list of words on land or underwater. It was found that participants were best at correctly recalling the words in the same environment in which they had initially learned them. For example, if a participant had learned the list of words underwater, they would perform better underwater than on land when they were

tested. This finding that context improves memory could be applied to both modalities of temporal negative priming. For example, with visual temporal negative priming, one could explore whether ignored repetition trials which had the same contextual background between the prime and probe had larger temporal negative priming than trials which had different contextual backgrounds between the prime and probe.

Finally, it is important to determine whether temporal negative priming may be affected by mental illness and individual differences. Previous research has indicated that spatial negative priming may be reduced for individuals with Alzheimer's disease and frequent cannabis users (Vaughan et al., 2006; Albertella et al., 2016). Likewise, individuals with schizophrenia and ADHD are shown to have decreased identity negative priming (Ungar et al., 2010; Ossmann, & Mulligan, 2003). The results of Experiment 1 did not find any correlations between temporal negative priming and either cannabis use or schizotypal personality traits. However, future research could look into whether individuals with mental illnesses which affect temporal reasoning, such as Korsakoff's Syndrome or Bálint's Syndrome, would exhibit reduced temporal negative priming (Malcolm, & Barton, 2007; Meudell, Mayes, MacDonald, & Pickering, 1991).

Concluding Remarks

As far as we are aware, this is the second known study exploring visual temporal negative priming and the first known study to expand it to the auditory domain. Not only do the results confirm the presence of temporal negative priming first discovered by Kahan et al. (2017), but these results support the trends previously found in negative priming reviews conducted by Frings, Schneider et al. (2014) and Mayr and Buchner (2007). According to these reviews, identity and spatial negative priming appear in both the visual and auditory domain. That is exactly what was found here. Temporal negative priming reflects an exciting and entirely new

class of negative priming that may help researchers better understand mechanisms involved in selective attention and cognitive control.

Although temporal negative priming does share similarities with other types of negative priming, it is distinct in several ways. Temporal negative priming cannot be considered a form of identity negative priming because the target items and the distractor items both in Kahan et al.'s (2017) study and in Experiments 1 and 3 remain consistent in the ignored repetition and control conditions. For example, Experiment 1 always used an X as the target, an O as the distractor, and participants were required to attend to the distractor for later use. This means that the negative priming found was not caused by participants attending to previously ignored stimuli, since none of our target stimuli were previously ignored. More parallels can be drawn between spatial and temporal negative priming than between identity and temporal. In fact, the original methodology for Kahan et al.'s (2017) study was modeled from a method originated by Neill and Kleinsmith (2016) in a spatial negative priming experiment. In both cases, it is the location (either temporal or spatial) of the prime distractor which conflicts with the location of the probe target. However, unlike spatial negative priming, all the stimuli in these experiments were situated in the exact same location on the screen or heard equally in both ears. The only difference in location was the temporal position of when a stimulus appeared, making it distinct from spatial negative priming. These findings are an exciting new addition to the realm of cognitive control research as they stand as a marker of an entirely new class of negative priming.

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Appendix

Experiment 1 Consent Form Bates College Department/Program of Psychology

Title of the Study: Attend, Don't Forget

Researcher Name(s): Alexa Harrison (aharriso@bates.edu); faculty advisor Prof. Todd Kahan (tkahan@bates.edu)

The general purpose of this research is to better understand how people attend to temporal information. Participants in this study will be asked to complete a number of computer tasks that will involve making rapid responses to letters shown on the computer screen. This will be followed by a demographics questionnaire. Findings from this study will be reported in my senior year empirical thesis and at the psychology department's poster presentation. There is also a possibility that this research will be defended to experts in the field and may be published at a later date.

I hereby give my consent to participate in this research study. I acknowledge that the researcher has provided me with:

- A. An explanation of the study's general purpose and procedure.
- B. Answers to any questions I have asked about the study procedure.

I understand that:

- A. My participation in this study will take approximately 45 minutes.
- B. The probability and magnitude of harm/discomfort anticipated as a result of participating in this study are not greater than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests. The demographics questions do cover some sensitive topics. However responses will never be associated with a person's name. Instead participants will make up their own 4 digit code and the researcher will never know this code and will never be able to link names with responses.
- C. The potential benefits of this study include a further understanding of the cognitive processes involved in attention and memory.
- D. I will be compensated for participating in this study with extra credit which I may apply to my psychology course.
- E. My participation is voluntary, and I may withdraw and discontinue participation in the study at any time. My refusal to participate will not result in any penalty or disadvantage.
- F. My responses in this study will be kept anonymous. All responses will be associated with a code that I invent and this code will never be linked with my name. The data will be stored in a secure location on a computer in Professor Kahan's psychology laboratory, and will only be available to myself, Alexa Harrison, and Professor Kahan. Research reports will only present findings on a group basis, without any personally identifying information.

If you consent to this study, please do not write your name. On the line below please draw a triangle in the place of your signature:

By drawing a triangle on this line, I agree to the terms of this study and I understand that I may terminate my participation at any time.

_____ Date: _____

Experiment 1 Debriefing Form
Bates College Department/Program of Psychology

Title of the Study: Attend, Don't Forget

Researcher Name(s): Alexa Harrison (aharriso@bates.edu); faculty advisor Prof. Todd Kahan (tkahan@bates.edu)

Thank you for participating in this research study. The goal of this project is to investigate the effect of temporal negative priming. Negative priming is the finding that the response to an item that was previously ignored will be slower and less accurate than the response to an item that was not previously ignored. This has been looked at with identity information. For example, if you are shown “ACA” and you must respond to the middle letter, people are slower to respond to “BAB” because they had just ignored the letter A. This has also been looked at with spatial locations; people are slower to respond to an object that appears at a location that was previously ignored. A new form of negative priming, called temporal negative priming states that people are slower to respond to things in time that they had previously ignored. See example below:

Note: in these examples time flows from left to right and “_” indicates an empty square.

Negative Priming Condition

Trial 1 _X_ O (respond “2” and ignore the 4th position)
 Trial 2 _ _ _ X (respond “4”, which had just been ignored)

Control Condition

Trial 1 _ X O_ (respond “2” and ignore the 3rd position)
 Trial 2 _ _ _ X (respond “4”, which had *not* just been ignored)

In the negative priming condition, the X on trial 2 (in the example above) appears in the temporal position that had just been ignored (contained a distractor on trial 1). At the end of the experiment you were asked a number of demographics questions about your mental health history and cannabis use. This is due to the fact that certain mental health conditions and heavy cannabis usage can hinder negative priming.

If you are interested in learning more about this study, please feel free to ask us questions in person, or contact us by email. If you would like to learn more about temporal negative priming, we recommend the following:

Tipper, S. P. (1985). The negative priming effect: Inhibitory priming by ignored objects. *The Quarterly Journal of Experimental Psychology*, 37,571–590

Kahan, T.A., Slowiaczek, L., & Altschuler, M. (2018). Temporal Negative Priming. Paper currently under review at *Journal of Experimental Psychology: General* (ask Prof. Kahan for a copy if interested)

If you have lost interest in recent activities, if you have difficulty getting motivated, or if you have been feeling down please be aware that help is available for any mental health concerns. For immediate care please call 207-786-6200 (then press 0). For more information visit <http://www.bates.edu/counseling-psychological-services/>

If you have any concerns about your rights as a participant in this study, please contact the Bates College Institutional Review Board (irb@bates.edu).

Experiment 2 Consent Form
Bates College Department/Program of Psychology

Title of the Study: Attend, Don't Forget Experiment 2

Researcher Name(s): Alexa Harrison (aharriso@bates.edu); faculty advisory prof. Todd Kahan (tkahan@bates.edu)

The general purpose of this research is to further understand how people attend to temporal information. Participants in this study will be asked to complete a number of computer tasks that will involve making rapid responses to different colored Xs shown on the computer screen. Findings from this study will be reported in my senior year empirical thesis and at the psychology department's poster presentation. There is also a possibility that this research will be defended to experts in the field and may be published at a later date.

I hereby give my consent to participate in this research study. I acknowledge that the researcher has provided me with:

- A. An explanation of the study's general purpose and procedure.
- B. Answers to any questions I have asked about the study procedure.

I understand that:

- A. My participation in this study will take approximately 45 minutes.
- B. The probability and magnitude of harm/discomfort anticipated as a result of participating in this study are not greater than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests.
- C. The potential benefits of this study include further understanding of the impact that items with similar characteristics have on temporal negative priming.
- D. I will be compensated for participating in this study with extra credit which I may apply to my psychology course.
- E. My participation is voluntary, and I may withdraw my consent and discontinue participation in the study at any time. My refusal to participate will not result in any penalty or disadvantage.
- G. My responses in this study will be kept confidential, to the extent permitted by law. The data will be stored in a secure location on a computer in Professor Kahan's psychology laboratory, and will only be available to myself, Alexa Harrison, and Professor Kahan. Research reports will only present findings on a group basis, without any personally identifying information.

Name (printed): _____

Signature: _____ Date: _____

Experiment 2 Debriefing Form
Bates College Department/Program of Psychology

Title of the Study: Attend, Don't Forget Experiment 2

Researcher Name(s): Alexa Harrison (aharriso@bates.edu); faculty advisor Prof. Todd Kahan (tkahan@bates.edu)

Thank you for participating in this research study. The goal of this project is to investigate whether people also experience temporal negative priming through auditory stimuli. Negative priming is the finding that the response to an item that was previously ignored will be slower and less accurate than the response to an item that was not previously ignored. This has been looked at with identity information. For example, if you are shown "ACA" and you must respond to the middle letter, people are slower to respond to "BAB" because they had just ignored the letter A. A new form of negative priming, called temporal negative priming states that people are slower to respond to things which they had previously ignored in time. See example below:

Match Condition

Trial 1 **b _ X _ X (respond "2" and ignore the 4th position)**
 Trial 2 **o _ _ _ X (respond "4", which had just been ignored)**

Mismatch Condition

Trial 1 **r _ X _ X (respond "2" and ignore the 4th position)**
 Trial 2 **g _ _ _ X (respond "4", which had just been ignored)**

Control Condition

Trial 1 **b _ X X _ (respond "2" and ignore the 3rd position)**
 Trial 2 **b _ _ _ X (respond "4", which had *not* just been ignored)**

The letter at the beginning of the sequence indicates which colored X will be the target. In the match condition, the prime distractor and the probe target Xs are the same color. In the mismatched condition, the prime distractor and the probe target Xs are mismatching colors. In the control condition, the prime distractor and the probe target do not occupy the same temporal location or require the same numeric response.

If you are interested in learning more about this study, please feel free to ask us questions in person, or contact us by email. If you would like to learn more temporal negative priming, we recommend the following:

Mayr, S., Buchner, A., Moller, M., & Hauke, R. (2011). Spatial and identity negative priming in audition: Evidence of feature binding in auditory spatial memory. *Attention, Perception & Psychophysics*, 73, 1710–1732.

Kahan, T.A., Slowiaczek, L., & Altschuler, M. (2018). Temporal Negative Priming. Paper currently under review at *Journal of Experimental Psychology: General* (ask Prof. Kahan for a copy if interested)

If you have any concerns about your rights as a participant in this study, please contact the Bates College Institutional Review Board (irb@bates.edu).

Experiment 3 Consent Form
Bates College Department/Program of Psychology

Title of the Study: Attend, Don't Forget Experiment 3

Researcher Name(s): Alexa Harrison (aharriso@bates.edu); faculty advisory prof. Todd Kahan (tkahan@bates.edu)

The general purpose of this research is to further understand how people attend to temporal information. Participants in this study will be asked to complete a number of tasks that will involve making rapid responses to different tones they hear. The findings from this study will be reported in my senior year empirical thesis and at the psychology department's poster presentation. There is also a possibility that this research will be defended to experts in the field and may be published at a later date. I hereby give my consent to participate in this research study. I acknowledge that the researcher has provided me with:

- A. An explanation of the study's general purpose and procedure.
- B. Answers to any questions I have asked about the study procedure.

I understand that:

- A. My participation in this study will take approximately 45 minutes.
- B. The probability and magnitude of harm/discomfort anticipated as a result of participating in this study are not greater than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests.
- C. The potential benefits of this study include further understanding of how timing sequences influence auditory negative priming.
- D. I will be compensated for participating in this study with extra credit which I may apply to my psychology course.
- E. My participation is voluntary, and I may withdraw my consent and discontinue participation in the study at any time. My refusal to participate will not result in any penalty or disadvantage.
- G. My responses in this study will be kept confidential, to the extent permitted by law. The data will be stored in a secure location on a computer in Professor Kahan's psychology laboratory, and will only be available to myself, Alexa Harrison, and Professor Kahan. Research reports will only present findings on a group basis, without any personally identifying information.

Name (printed): _____

Signature: _____ Date: _____

Experiment 3 Debriefing Form
Bates College Department/Program of Psychology

Title of the Study: Attend, Don't Forget Experiment 3

Researcher Name(s): Alexa Harrison (aharriso@bates.edu); faculty advisor Prof. Todd Kahan (tkahan@bates.edu)

Thank you for participating in this research study. The goal of this project is to investigate whether people also experience temporal negative priming through auditory stimuli. Negative priming is the finding that the response to an item that was previously ignored will be slower and less accurate than the response to an item that was not previously ignored. This has been looked at with identity information. For example, if you are shown "ACA" and you must respond to the middle letter, people are slower to respond to "BAB" because they had just ignored the letter A. A new form of negative priming, called temporal negative priming states that people are slower to respond to things which they had previously ignored in time. See example below:

Note: in these examples time flows from left to right. The "T" indicates the target tone, the "D" indicates the distractor tone and the "_" are the neutral tones.

Negative Priming Condition

Trial 1 _ T _ D (respond "2" and ignore the 4th position)
 Trial 2 _ _ _ T (respond "4", which had just been ignored)

Control Condition

Trial 1 _ T D _ (respond "2" and ignore the 3rd position)
 Trial 2 _ _ _ T (respond "4", which had *not* just been ignored)

In the negative priming condition, the T on trial 2 was heard at the same temporal position as the D (which should be ignored) from trial 1. We predict that participants will be much slower to responding to the T in trial 2 in the negative priming condition than the control condition.

If you are interested in learning more about this study, please feel free to ask us questions in person, or contact us by email. If you would like to learn more temporal negative priming, we recommend the following:

Mayr, S., Buchner, A., Moller, M., & Hauke, R. (2011). Spatial and identity negative priming in audition: Evidence of feature binding in auditory spatial memory. *Attention, Perception & Psychophysics*, 73, 1710–1732.

Kahan, T.A., Slowiaczek, L., & Altschuler, M. (2018). Temporal Negative Priming. Paper currently under review at *Journal of Experimental Psychology: General* (ask Prof. Kahan for a copy if interested)

If you have any concerns about your rights as a participant in this study, please contact the Bates College Institutional Review Board (irb@bates.edu).