Attentional blink reflex modulation in a continuous performance task is modality specific

Author

Lipp, OV, Neumann, DL

Published

2004

Journal Title

Psychophysiology

DOI

https://doi.org/10.1111/j.1469-8986.00165.x

Copyright Statement

Downloaded from

Link to published version

https://onlinelibrary.wiley.com/doi/10.1111/j.1469-8986.00165.x

Griffith Research Online

Attentional blink reflex modulation in a continuous performance task is modality specific

Ottmar V. Lipp[1] & David L. Neumann[2]
[1]School of Psychology, University of Queensland, Australia
[2]School of Applied Psychology, Griffith University, Australia

Running head:

Blink modulation in a continuous performance task

Address for correspondence:

Ottmar V. Lipp, PhD, School of Psychology, The University of Queensland, QLD, 4072, Australia.
E-mail: o.lipp@psy.uq.edu.au.

Acknowledgments:

Grant A10027218 from the Australian Research Council supported this work.

Abstract

Four experiments investigated the attentional modulation of the acoustic blink reflex during a continuous spatial tracking task. Experiment 1 found smaller blink magnitudes during a visual tracking task in comparison to a non-task condition that provided continuous stimulus input. Using two different probe positions, Experiment 2 replicated this finding and also found blink latency slowing in the task condition. Experiment 3 varied the difficulty of the visual tracking task. Contrary to expectations, blink inhibition was significant only in the easy condition and larger in the easy than in the difficult task. Blink latency lengthening did not differ across conditions and was significant at both levels of task difficulty. Experiment 4 employed visual and acoustic Tracking tasks that were less difficult than the ones used in Experiment 3, at two levels of task load. Blink magnitude modulation, inhibition during the visual task and facilitation during the acoustic task, was significant at the high level of task load in both modality groups. Blink latency was lengthened in all visual task conditions and shortened in the difficult acoustic task. The present series of experiments provides convincing evidence that attentional blink modulation in a continuous spatial tracking task is modality specific.

Reflex modulation has gained increasing popularity as a probe for psychological processes over the last decade. In research on emotion, the startle reflex has been instrumental in the delineation of the neural circuitry that mediates fear responses in rodents (Le Doux, 2000) and in the resurgence of interest in the experimental analysis of emotion in humans (Lang, Bradley, & Cuthbert, 1990). In research on attentional processes, blink reflexes have been employed in the investigation of information processing in basic research as well as in experimental psychopathology (Hackley, 1999). Most of these studies have focussed on attentional processes that occur shortly after the onset of a discrete stimulus, such as sensory gating, which are thought to be deficient in some psychopathologies (Braff, Geyer, & Swerdlow, 2001). However, some studies have used the blink reflex probe to investigate attentional processes that occur at later stages of information processing (Putnam & Vanman, 1999). An issue that is of interest in these studies, but one that also has implications for studies of emotion that employ blink reflex probes, is the role of the sensory modalities in which to-be-attended and probe stimuli are presented.

The question of whether the effects of attention on blink reflexes are affected by stimulus modality is of interest for two reasons. The first reason is that it permits inferences as to the nature of the attentional process under investigation (Graham, 1992). Modality specificity of attentional blink modulation is present if blinks are larger during attended that during ignored foreground stimuli presented in the same sensory as the blink-eliciting stimuli, but are smaller during attended than during ignored foreground stimuli presented in a different sensory modality. Modality specificity of attentional blink modulation is reflective of an early selection process as attending to a foreground in one modality inhibits stimulus input in different modalities at a point prior to the convergence of sensory inputs from these different sensory modalities. Modality non-specificity of attentional blink modulation, however, is best understood in a late selection account. The second reason is more pragmatic in nature. Previous research has used modality specificity as a means to distinguish between emotional and attentional blink modulation (Putnam & Vanman, 1999). Emotional blink modulation, the affect-startle effect, is uniform across emotion inducing stimuli in the visual, acoustic, or olfactory domains (Bradley, Cuthbert, & Lang, 1999). If effects of attention on blink reflex modulation prove to be modality specific, a distinction between emotional and attentional reflex modulation, or at least their predominance in a certain situation, can be made easily. On the other hand, if attentional blink reflex modulation were modality non-specific, such a separation would be more difficult.

Early research on the topic (Anthony & Graham, 1985; Putnam, 1990) suggested modality specificity of attentional blink reflex modulation. Anthony and Graham found larger blink reflexes during interesting than during dull stimuli when foregrounds and reflex stimuli were presented in the same modality, but the reverse when they were presented in different modalities. Putnam summarises a series of reaction time studies in which acoustic blink reflexes were facilitated during acoustic warning stimuli, but inhibited during visual or tactile warning stimuli. Moreover, the extent of blink modulation, facilitation or inhibition, was enhanced towards the end of the preparatory interval. More recent studies that employed passive and active attention paradigms have provided different results, however.

Lipp and colleagues have shown in a series of studies that blinks elicited at long lead intervals during attended stimuli are larger than blinks elicited during non-attended stimuli regardless of the modality of foreground or blink-eliciting stimulus. This pattern of results emerged in a habituation paradigm that employed a change in the modality of the habituation stimulus as a means to engage attention (Lipp, Neumann, & McHugh, 2003) and in explicit task situations such as RT tasks (Lipp, Siddle, & Dall, 2000) or a discrimination and counting task (Lipp, Neumann, Pretorius, & McHugh, 2003; Lipp, Siddle, & Dall, 1998; Lipp, Siddle, & Dall, 2000). These findings, which have been confirmed in other laboratories (Böhmelt, Schell, & Dawson, 1999), contrast with the earlier reports of modality specificity. This discrepancy in results, particularly given that, for instance, those in the reaction time tasks were obtained in quite similar procedures, raises the question as to whether it is possible to characterise the task conditions under which modality specificity or non-specificity of attentional blink modulation will be observed.

Initially, we had speculated that task difficulty might be a critical variable (Lipp et al., 2000). Given that early inhibition of sensory input is a strategy that can be potentially dangerous in that important information in a non-attended modality can be overlooked, it seemed reasonable to assume that it is not utilised as the default. Thus, modality non-specificity may be found in simple tasks, whereas modality specificity may be found if task demands are high. Studies that employed discrimination and counting tasks or reaction time tasks at different levels of task difficulty failed, however, to provide clear support for this notion. Thus, if a transition from modality non-specificity to modality specificity cannot be observed within a task domain, then it may be that it is possible to see it across different task domains.

The studies of attentional blink modulation reviewed so far employed trial structured procedures in which successive foreground stimuli were separated by intertrial intervals of at least 10 to 15 seconds. There are, however, two studies available that assessed attentional modulation of acoustic blink during continuous performance tasks presented in the visual modality (Hazlett, Dawson, Schell, & Nuechterlein, 2001; Neumann, 2002). Hazlett et al. presented participants with a continuous performance test in the format of a digit sequence task. Participants watched a stream of digits that appeared for 50 ms each at regular intervals, one every 1650 ms, on a computer screen and were asked to press a button whenever the digit 3 was followed by a 7. Acoustic blink-eliciting stimuli were presented at two lead intervals, 120 and 1200 ms, after the presentation of a digit 3, after a digit 0, or after a digit 3 that coincided with the presentation of a task irrelevant tone. Blink modulation was assessed in comparison to control blinks collected during a no task baseline period that preceded and followed each of two task sequences. Blinks elicited during the task session at the short lead interval were inhibited, and inhibition was larger following the target digit than following the non-target. More interesting within the present context, blinks elicited at the long lead interval were inhibited during all three trial types. However, there was no difference in the extent of blink inhibition during target and non-target stimuli. Thus, the effect of selective attention that was present at short lead intervals was not found at the long lead interval.

Neumann (2002) required his participants to perform a visual monitoring task under single and multiple task conditions. In the single task condition, participants used a joy stick to track the movements of a cross along a horizontal axis. In the multiple task condition, participants performed a gauge monitoring task simultaneously with the tracking task. The gauge monitoring required that participants reset any of 6 gauges whenever the gauges displayed values in a critical range. In addition to blink reflexes, the number of spontaneous blinks, heart period and verbal ratings of mental workload were recorded. The verbal measures of mental workload and the traditional physiological indices confirmed that attentional demands were increased during the multiple task condition as participants displayed fewer spontaneous blinks and shorter heart periods. Reflex blinks elicited by an acoustic stimulus during the task conditions were smaller in magnitude and longer in latency in comparison to blinks elicited during no task baseline periods that were completed before and after the task trials. Moreover, blink inhibition was greater during the multiple task condition than during the single task condition. Thus, in addition to confirming the utility of blink reflex modulation as a measure of workload, Neumann's data provide support for a modality specific account of attentional blink reflex modulation.

The results of both studies that employed a continuous performance task suggest the presence of modality specific attentional blink modulation. Hazlett et al. (2001) found that acoustic blinks elicited while participants monitored a visual display were inhibited relative to a control baseline. Moreover, Neumann (2000) found this inhibition to be enhanced during a more difficult task. However, the previous studies did not include a direct comparison across different modalities of foreground stimulation. This was the purpose of the present study. The present study was designed to assess attentional blink modulation during a continuous performance task that could be presented in a similar fashion in the visual or acoustic domains. Moreover, the task was designed to offer the provision for variations of task difficulty. A spatial attention task involving either visual or acoustic cues was implemented. Participants were presented with sequences of either visual or acoustic stimuli that originated from different spatial locations. They were asked to count how often a particular movement pattern occurred, e.g. three or more consecutive movements to the right or to the left. Difficulty was manipulated by either presenting the stimuli at a constant duration, 3 s, or at randomly varying durations. Experiments 1 to 3 were conducted to establish the task and to assess the effectiveness of the difficulty manipulation. Experiment 4 contrasted acoustic and visual foreground stimuli in easy and difficult task conditions.

Experiment 1

Experiment 1 assessed modulation of acoustic blink reflexes during a visual continuous performance task. Blinks elicited during a task condition in which participants had to track the movements of a visual cue were compared to blinks elicited during a control condition in which a constant visual stimulation was presented. The control condition was included because previous research has shown that continuous stimulus input per se can prime blink reflexes (Lipp et al., 2003).

Method

Participants

Three male and thirteen female students from the University of Queensland provided informed consent and participated in exchange for course credit. One female participant did not follow the instructions correctly and her data was excluded from the statistical analyses. The remaining participants were aged between 17 and 21 years (M = 18.6 years, SD = 1.06) and were allocated at random to receive one of three trial orders.

Apparatus

Electromyographic (EMG) activity was recorded from the left orbicularis oculi with two domed Ag/AgCl miniature electrodes filled with Surgicon E10 electrolyte. One of the electrodes was attached 1 cm under the pupil of the left eye and the second was 1.5 cm lateral. A ground electrode was attached to the inside of the left forearm. The raw EMG signal was amplified with a Grass 7P3C AC preamplifier set with a 0.5 amplitude high-pass cutoff of 10 Hz and a low-pass cutoff of 3000 Hz. Following amplification, the raw EMG was digitized and sampled on-line with a sampling rate of 1000 Hz. Sampling of the signal began 100 ms before and ended 400 ms after the onset of the blink-eliciting stimulus. The blink-eliciting stimulus was a white noise presented via Sennheisser HD25-1 stereophonic headphones. The white noise was produced by a custom built apparatus and set at an intensity of 105 dB(A), a duration of 50 ms, and an instantaneous rise time. All auditory stimuli were calibrated with a Brüel & Kjær Type 2205 sound level meter.

The visual lead stimuli were generated by seven 10 mm green light emitting diodes (LEDs, operating voltage 1.7-2.8V, current 10-20mA; luminance 5-15mCd) that were individually housed in 5 x 8 x 3 cm black plastic boxes. The boxes were mounted on separate stands such that the LED was located 90 cm above the ground at the participant's eye level. The seven LEDs were placed in a 140° arc such that one LED was positioned directly in front of the participant and three LEDs were positioned at equally spaced intervals to the left and to the right of the central LED. Each LED was positioned 1 m from the participant.

Procedure

Upon arrival, participants provided informed consent and cleaned the skin under the left eye with soap and water. The participant was seated in the experimental chamber and electrodes were attached. The experiment was controlled and monitored from an adjoining room. To confirm the fidelity of the EMG recording, the participant was presented with up to three blink-eliciting stimuli. Next, the participant was informed that the purpose of the experiment was to record physiological data while performing three different tasks of three minutes each. During the Tracking task, participants were asked to follow the LEDs as they were turned on and off in a semi-random pattern. At the start of the task, the central LED would turn on for a short period of time. Switching off of the LED would coincide with the switching on of the LED to the left or right of the central one. Illumination of this LED would be followed by the illumination of the LED to the left or the right of it and so forth. Participants were informed that the sequence of illuminations was random and that they were to count how often the illumination shifted into the same direction for three or more times consecutively and to report the count after the end of the task. In the second task, the Stimulus only task, only the central LED was illuminated for three minutes. Participants were instructed to maintain their gaze on the LED throughout the entire trial. Finally, in the third task, the No stimulus task, no LED was illuminated. Participants were asked to gaze towards the opposite wall for three minutes.

A 2 min acclimatization period followed the instructions during which participants were asked to sit quietly. During the subsequent experiment proper, three blocks of each of the three tasks (Tracking, Stimulus only, and No stimulus) were presented. The order of the tasks within each block was counterbalanced in a Latin square to minimise the effects of blink reflex habituation. The sequence of tasks within a block was counterbalanced across participants. Participants were informed as to the requirements at the beginning of each task.

Three different random sequences of LED illuminations were developed for the Tracking task by determining at random whether illumination of one LED would be followed by illumination to the left or the right. Illumination of the LED at the outermost positions was always followed by an illumination of the LED closer to the center. Each illumination lasted for 3 s and a total of 60 illuminations was presented, which resulted in a task duration of 3 min. Each task began with an illumination of the central LED. At the conclusion of the task, the experimenter prompted the participant to report the total count and the participant was given feedback as to accuracy of the answer. In the Stimulus only tasks, the central LED was illuminated for 3 min. In the No stimulus task, no LED was illuminated.

Six blink-eliciting stimuli were presented during each task. The blink-eliciting stimuli were scheduled by dividing the task into six segments of 30 s and one blink-eliciting stimulus was presented per segment. Initially, the timing of the blink-eliciting stimulus during the 30-sec block was determined at random. The timing was then adjusted with reference to the closest LED onset in the Tracking task, such that each blink-eliciting stimulus was presented 2600 ms following the closest LED onset. The same schedule of blink-eliciting stimuli was used in the Stimulus only and No stimulus tasks. No blink-eliciting stimulus occurred within the first 10 s of a task or within 15 s of another blink-eliciting stimulus.

Immediately after the last Tracking task, participants were asked to provide a rating of the attentional demands of the task. Participants were initially given a definition of mental effort as used in the Mental Demand subscale of the NASA Task Load Index (Hart & Staveland, 1988) and were asked to make a rating of the task demands using the modified Cooper-Harper rating scale (Wierwille & Casali, 1983). This scale uses a decision tree to lead participants to rate the workload demands between 1 (very easy, highly desirable difficulty) and 10 (impossible difficulty). The participants were debriefed at the conclusion of the experiment.

Response definition and statistical analysis

The EMG signal was rectified, filtered, and integrated with a Butterworth low-pass filter (time constant: 80 ms). Blink magnitude and latency were scored from the integrated response curve by a trained scorer who used a custom-written program. Latency was measured as the time between the onset of the blink-eliciting stimulus and the point at which 10% of the maximum response slope was reached. Response magnitude was defined as the difference in A/D units between the peak of the integrated response and the response onset. EMG recordings that fluctuated more than 20 μV during the 100 ms prior to the onset of the blink-eliciting stimulus were rejected. If on a trial there was no detectable peak, latency was scored as missing and magnitude was scored as zero. All zero magnitude values were included in the analysis.

As an index of task performance, error scores were calculated as the absolute value of the difference between the reported count and the correct count for each Tracking task and averaged across trial blocks. Blink reflex magnitude and latency were averaged separately for each trial type

(Tracking, Stimulus only, No stimulus). To correct for the considerable individual variability in blink magnitude and latency, change scores were calculated using the blink reflexes during the No stimulus tasks as baseline of responsiveness. Blink magnitude was expressed as a percentage change, for instance, for the Stimulus only task, the formula (Stimulus only – No stimulus) / No stimulus * 100 was used. A negative percentage change reflects blink magnitude inhibition relative to the baseline, whereas a positive percentage change reflects blink magnitude facilitation. Blink latency change was calculated as a simple difference score (e.g., Tracking – No stimulus). A positive change score reflects blink latency lengthening, whereas a negative score reflects latency shortening.

To test the hypothesis that performance of an attention demanding continuous visual task would reduce acoustic blink reflexes, blinks during the Tracking task were compared with blinks during the Stimulus only task. An initial 2 x 3 (Task type x Trial block) ANOVA failed to find evidence for an effect of the factor trial. Thus, magnitude and latency change scores from the Tracking and Stimulus only tasks were averaged across trials and compared with t-tests.

Results and Discussion

The mean workload rating was 2.9 (SD = .59). Participants tended to make few errors on the tracking task as indicated by a low mean error score of .16 (SD = .21). Blink reflex magnitude was inhibited during the Tracking task (M = -23.71, SD = 30.81) and was smaller than during the Stimulus only task (M = .98, SD = 26.84), t(14) = 2.60, p<.05. Blink latency change did not differ between the experimental conditions (Tracking trials, M = .50 ms, SD = 3.24; Stimulus only trials, M = -.37 ms, SD = 2.08), t(14) < 1.2.

The present results replicate reports by Hazlett et al. (2001) and Neumann (2002) of inhibition of acoustic blink during a continuous visual performance task. Contrary to the data reported by Hazlett et al., blink inhibition was larger during the Tracking task than during a Stimulus only condition. However, the lack of selective attention effects on blink magnitude modulation at long lead intervals reported by Hazlett et al. may reflect a ceiling effect. Hazlett et al. recorded control blinks on non-target control trials during the continuous performance task, which overall seemed more demanding than the task used here. Contrary to Neumann (2002), who reported slower blink latencies with increasing task load, no effect was found on latency modulation. This may reflect on the fact that a constant lead interval was used across all trials which may have rendered the probes, although infrequent, quite predictable. Experiment 2 addressed this option by including a second lead interval of 600 ms in the Tracking task.

Experiment 2

Method

Participants

Twelve male and thirteen female undergraduate students who had not participated in Experiment 1 provided informed consent and received course credit for participation. The data of four participants were excluded from the analyses: one female for not following the instructions; one female due to equipment malfunction; one male due to excessive non-responsiveness to the blink-eliciting stimulus; and one female due to an excessive number of extreme blinks. The remaining 21 participants were aged between 17 and 23 years (M = 19.6, SD = 1.8).

Apparatus, procedure, response definition and statistical analysis

The apparatus and procedure were the same as in Experiment 1 with the exception of the timings of the blink-eliciting stimulus. The blink-eliciting stimuli were re-scheduled such that there were three presentations each at the lead intervals of 600 ms and 2600 ms during the Tracking task. The order of the lead intervals was arranged at random.

Response indices were derived as in Experiment 1. Blink magnitude and latency change scores were subjected to separate 2 x 2 (Task type x Lead interval) ANOVAs. The factor Lead interval is a dummy variable for the data from the Stimulus only task. Responses that occurred in the same serial position as in the respective Tracking task condition were allocated to the two levels of the factor.

Results and Discussion

The workload rating of 2.56 (SD = .76) was similar to that in Experiment 1. The mean error on the counting task was .29 (SD = .28). As shown in the left panel of Figure 1 and replicating the findings of Experiment 1, blink magnitude was significantly inhibited during the Tracking task relative to the Stimulus only task, main effect Task $F(1, 20) = 14.25$, $MSE = 640$, $p<.01$. In addition, blink magnitude inhibition was greater at the 2600 than at the 600 ms lead interval, main effect Lead interval $F(1, 20) = 11.43$, $MSE = 369$, $p<.01$. The Task type x Lead interval interaction was not significant, $F < 1.10$. The right panel of Figure 1 shows that blink latency was slowed during the Tracking task and that the extent of slowing was greater at the 600 ms than at the 2600 ms lead interval. Statistical analyses confirmed these impressions yielding main effects for Lead interval $F(1, 20) = 4.54$, $MSE = 8.19$, $p<.05$, and Task type $F(1, 20) = 35.03$, $MSE = 8.46$, $p<.001$. The Task type x Lead interval interaction was not significant, $F < 1.30$.

Insert Figure 1 about here

Experiment 2 confirmed the findings of Experiment 1 and, in addition, yielded evidence for blink latency slowing during the Tracking Task. Thus, the data are consistent with the results of previous studies and confirm that the visual spatial attention task employed here is a preparation well suited for the assessment of the effects of sustained attention on blink reflex modulation. It seemed that the addition of a second lead interval permitted the observation of latency slowing in the present task. Moreover, it is interesting to note the inconsistencies in the relationship between blink magnitude inhibition and blink latency slowing. In the tracking task, blink magnitude inhibition and blink latency slowing were larger than in the Stimulus only task. Across lead intervals, however, increased blink magnitude inhibition seemed to be associated with reduced blink latency slowing. This finding, together with the dissociation of blink magnitude and latency modulation seen in Experiment 1, seems to indicate that blink magnitude and latency change convey distinct information, in particular in experiments on attentional blink modulation.

Experiment 3

Experiments 1 and 2 confirmed the utility of the visual spatial tracking task as a procedure for the investigation of attentional blink modulation. Experiment 3 aimed to extend the initial findings by adding a manipulation of task difficulty. A second version of the tracking task was employed that varied the duration of LED illuminations. In addition, the No stimulus baseline was omitted and the Stimulus only condition was employed to obtain baseline responses. It was predicted that the extent of blink magnitude modulation would be enhanced in the more demanding variable task condition.

Method

Participants

The participants were five male and twenty female students who had not participated in the earlier experiments. All participants provided informed consent. The data from five participants were rejected, one female for failing to follow instructions and one male and three females due to excessive missing blink reflex data. The age for the remaining participants ranged between 18 and 35 years (M = 20.1, SD = 5.0).

Apparatus, procedure, response definition, and statistical analysis

The apparatus was the same as described in Experiment 1. The procedure followed that used in Experiment 2, however, the No stimulus task was replaced with a second tracking task. In the new tracking task, designated as Variable duration task, the duration of the lead stimuli varied between 250, 500, 750, 1000, 2500, and 3000 ms. The order of the lead stimulus durations was varied at random with the restriction that the blink-eliciting stimuli were presented at the same temporal locations relative to the onset of the trial as in the Constant duration task. As the lead intervals were 600 and 2600 ms, the sequencing of the lead stimulus durations was restricted as a lead interval of 750 to 3000 ms was needed for the 600 ms probe and a lead interval of 3000 ms was needed for the 2600 ms probe. In addition to the Constant duration and Variable duration Tracking tasks, a Stimulus only task was presented. The three tasks were arranged into three blocks as described in Experiment 1. Participants provided a rating of the task demands at the conclusion of the last Constant duration and Variable duration task of the experiment.

Separate t-tests were calculated for error scores and ratings to compare the two versions of the Tracking task. The calculation of blink magnitude and latency change scores was performed as in Experiment 1 with the exception that responses from the Stimulus only task served as the measure of the participant's baseline level of responding. To assess whether blink modulation was significant during the tracking tasks, the 95% confidence intervals of the mean were inspected. Blink modulation was regarded as significant if zero was outside the confidence interval. Separate 2 x 2 (Duration x Lead interval) ANOVAs were conducted on blink magnitude and latency change scores to assess effects of task difficulty and lead interval. Post hoc comparisons were performed with t-tests that were adjusted for the accumulation of Type I error by using Šidák's multiplicative inequality (Rohlf & Sokal, 1981).

Results

Participants committed fewer errors in the Constant duration condition (M = .78, SD = 1.4) than in the Variable duration condition (M = 3.44, SD = 2.81), t(20) = 5.17, p<.001, and rated the workload as lower (Constant: M = 2.95, SD = 2.95; Variable M = 4.67, SD = 2.29), t(20) = 4.86, p<.001. Figure 2 shows the mean blink magnitude (left panel) and blink latency change (right panel) during the two Tracking tasks.

Insert Figure 2 about here

Contrary to expectation, blink magnitude inhibition seemed smaller during the Variable than during the Constant task conditions. This impression was confirmed by the analysis which yielded a main effect for Duration F(1, 20) = 7.43, MSE = 727, p<.05 , and a Duration x Lead interval interaction, F(1, 20) = 6.71, MSE = 205, p<.05. The interaction reflected that blink magnitude inhibition was larger in the Constant than in the Variable task condition at the 2600 ms lead interval, t(20) = 3.32, p<.05, but not at the 600 ms lead interval, t(20) < 1.90. Inspection of the confidence intervals revealed that blink magnitude was inhibited significantly at both lead intervals in the Constant task condition, but not in the variable task condition. As indicated in the right panel if Figure 2, blink latency slowing was significant at both lead intervals in both task conditions. Blink latency slowing was larger at the 600 ms lead interval, main effect for Lead interval, F(1 ,20) = 17.58, MSE = 8.84, p<.001, but did not differ across task conditions, all other F < 2.90.

Discussion

The aims of Experiment 3 were to replicate the finding of blink magnitude inhibition and latency slowing during the Tracking task as seen in Experiment 2, and to introduce a second version of the task in order to assess the effects of enhanced task difficulty on attentional blink reflex modulation. The results obtained in the Constant task condition replicate those from Experiment 2. Blink magnitude was inhibited and blink latency was slowed relative to the Stimulus only control baseline. In addition, the extent of blink latency slowing was smaller at the long lead interval. Error and rating data indicate that the Variable duration condition was more difficult than was the Constant duration condition. This increase in task difficulty did not, however, coincide with an enhancement of blink modulation. Rather, the extent of blink magnitude inhibition was reduced and the extent of blink latency slowing, although significant, was not larger than that in the Constant condition.

One may argue that the present failure to find larger blink inhibition during the variable Tracking task indicates that the present effects of sustained attention on blink are not modality specific after all. Lipp et al. (2000) reported that blink facilitation in a reaction time task increased with increased task difficulty regardless of the modality of the to be attended stimulus. Thus, it may be that the present finding of larger blinks in the Variable condition may reflect a modality non-specific effect of task difficulty. This interpretation is, however, not consistent with the finding of significant blink inhibition during the Constant task condition. Inhibition of blink relative to stimulus only or no stimulus controls was not observed in the low demand task conditions used by Lipp et al. Post hoc analyses of the data from the variable task condition suggest a second interpretation. The number of errors committed in the Variable task condition varied considerably across blocks and participants, ranging from 0 to 19. This is well above the range observed in the Constant condition of 0 to 7. Thus, one may argue that some of the participants on some of the task blocks found the Variable task very difficult to do to the extent that they ceased to pay attention to the changing positions of the LEDs and resorted to guessing. This would have rendered the Tracking task equivalent to a Stimulus only condition. This interpretation is supported by the finding that participants, who, in the Variable condition, made more errors, had a tendency to have larger blinks than participants who made fewer errors. This account does not explain, however, the significant latency slowing in the Variable task condition that was found in absence of blink magnitude inhibition.

Experiment 4

Given the failure to find significant blink magnitude inhibition during the Variable Tracking task used in Experiment 3, it was decided to use an overall simpler version of the Tracking task for the comparison of visual and acoustic spatial attention tasks in Experiment 4. This decision was also supported by participant's failure to perform an acoustic analogue of the Continuous Tracking task used in Experiments 2 and 3 in a pilot experiment. In order to simplify the overall task, the number of different spatial locations was reduced from 7 to 3. The stands from which the stimuli originated were placed in front of the participant or 45° to the left or right.

Experiment 4 will also determine whether the increased task difficulty caused the larger blinks in the Variable task condition. If task difficulty enhanced blink in the Variable task conditions of Experiment 3, then a similar trend should be found across both modality conditions. If, however, blink modulation in the present continuous performance task is modality specific, then the extent of blink modulation, inhibition in the visual condition and facilitation in the acoustic condition, should increase with increased task difficulty.

Method

Participants

Ten male and 19 female undergraduate students who had not participated in earlier experiments provided informed consent prior to participation. The data from two female participants was excluded due to excessive missing blink reflex data. Upon arrival at the laboratory, participants were allocated at random to one of two groups such that the proportion of males and females in each group was similar (Acoustic: 5:8, Visual: 5:9). The participants were aged between 17 to 42 years (M = 20.4 years, SD = 6.7).

Apparatus, procedure, response definition, and statistical analysis

Experiment 4 employed three of the LED stands described in Experiment 1. The acoustic task stimuli were presented by piezo electrical buzzers (3-14V DC 91dB operated at 2 - 5V range with acoustic dampening) mounted in the plastic box, 1 cm below the LED on each stand. The intensity of the buzzers was set for each participant in the Acoustic group prior to the commencement of the experiment to ensure that the perceived intensity of the tone matched that of the light. In this procedure, the intensity of the light was kept constant and the intensity of the buzzers was increased in a staircase procedure until the participant reported that the intensities of the tone and light matched. The final buzzer intensity was used throughout the experiment.

Prior to the three blocks that comprised Tracking tasks and Stimulus only tasks, a No stimulus baseline task was completed. Participants were instructed to sit quietly for 3 min while their blink reflexes were assessed. The blink-eliciting stimulus was presented six times as in the No stimulus task in Experiment 1. Responses in the No stimulus task were used to ascertain whether the groups differed in overall responsiveness to the blink eliciting stimulus. The experiment proper consisted of three blocks each comprising two tracking tasks (Continuous and Variable), and a

Stimulus only task. In the tracking task, only three different locations were used. Participants in both groups were asked to count how often the stimulus (LED illumination or tone) moved from the left, to the center, and then to the right spatial locations, or vice versa, in one consecutive movement. In the stimulus only tasks, the lead stimulus was a 3 min illumination of the central LED or a 3 min presentation of the central tone. The three trial types were presented in three different orders across trial blocks according to the procedure described in Experiment 1.

Error on the tracking task and ratings of the task demands were examined with separate 2 x 2 (Modality x Duration) ANOVAs. To confirm that the baseline level of responsiveness was comparable in the modality groups, blink magnitude and latency of blinks elicited during the No stimulus task were compared with between groups t-tests. No differences were found in blink magnitude, t(25) < 1.50, or latency, t(25) < 1.20. Blink magnitude and latency change scores were calculated as in Experiment 3, i.e., the Stimulus only tasks were used as baseline. The 95% confidence intervals of the mean were inspected to determine if blink modulation was significantly different from baseline. Separate 2 x 2 x 2 (Modality x Duration x Lead interval) ANOVAs were conducted on blink magnitude and latency change scores.

Results and Discussion

The analysis of the error data yielded main effects for Duration, F(1, 25) = 91.61, MSE = 7.84, p<.001, and Modality, F(1, 25) = 26.14, MSE = 13.27, p<.001, and a Modality x Duration interaction, F(1, 25) = 21.50, MSE = 7.84, p<.001. The interaction reflects that in the Variable task, participants committed more errors in the acoustic task (13.01, SD = 4.06) than in the visual task (4.40, SD = 4.65), t(25) = 8.14, p<.01, whereas there was no difference between modality conditions in the Constant task (Acoustic: 2.18, SD = 1.82; Visual: .62, SD = .79), t(25) < 1.50. Participants rated the acoustic task as more difficult than the visual task, main effect Modality, F(1, 25) = 9.58, MSE = 5.23, p<.01, and the Variable task as more difficult than the Constant task, main effect Duration F(1, 25) = 17.48, MSE = 1.81, p<.001 (Acoustic/constant: 3.54, SD = 2.37; Acoustic/variable: 5.46, SD = 2.47; Visual/constant: 2.0, SD = .78; Visual/variable: 3.14, SD = 1.46). The Modality x Duration interaction was not significant, F < 1.20.

Insert Figure 3 about here

Figure 3 (upper panel) shows that blink magnitude during the tracking task was facilitated in the Acoustic group, but inhibited in the Visual group. Magnitude modulation seemed more pronounced in the Variable condition. The statistical analyses confirmed this impression yielding main effects for Duration, F(1, 25) = 6.08, MSE = 789, p<.05, and Modality, F(1, 25) = 9.25, MSE

= 3083, p<.01, and Modality x Duration, F(1, 25) = 14.79, MSE = 789, p<.01, and Duration x Lead interval interactions, F(1, 25) = 12.56, MSE = 196, p<.01. All other effects were not significant, all Fs <1.10. The Duration x Lead interval interaction reflects that during Constant tasks, blinks were smaller at the 2600 ms than at the 600 ms lead interval, t(25) = 3.62, p<.05, whereas there was no difference for Variable tasks, t(25) < 1.50. The Modality x Duration interaction is due to the fact that in the acoustic task, blink modulation was larger in the Variable than in the Constant condition, t(25) = 4.55, p<.01, whereas there was no difference in the visual task. Moreover, blink modulation differed between the two modality groups in the Variable Tracking task, t(25) = 7.10, p<.01, but not in the Constant Tracking task, t(25) < 1.60. Inspection of the confidence intervals confirmed that in the Variable Tracking task, blink magnitude was significantly facilitated at both lead intervals in the Acoustic condition, but inhibited in the Visual condition. Moreover, blink was inhibited at the 2600 ms lead interval in the visual Constant Tracking task.

Blink latency tended to be shortened in the Acoustic group and lengthened in the Visual group (see Figure 3, bottom panel). Inspection of the confidence intervals indicated that blink latency lengthening in the Visual group was significant in all experimental conditions. In the Acoustic group, blink latency shortening was significant at the 2600 ms lead interval for the Variable Tracking task only. Blink latency was shorter in the Acoustic than in the Visual group, main effect Modality, F(1, 25) = 27.13, MSE = 25.22, p<.001, and shorter at the 2600 ms than at the 600 ms lead interval, main effect Lead interval, F(1, 25) = 9.25, MSE = 6.82, p<.01. All other main effects and interactions were not significant, all other Fs < 1.67.

The results of Experiment 4 confirm the notion that attentional blink modulation during the continuous performance task is modality specific. In the acoustic tracking task blink magnitude modulation increased with increasing task demands. Moreover, blink magnitude modulation, inhibition in the visual task and facilitation in the acoustic task, was significant predominantly during the Variable task condition. Blink latency showed a similar pattern of results, although the pattern was less clear in that the differences between the task conditions were smaller. The present results are not consistent with the notion that enhanced task difficulty results in larger blinks in a continuous tracking task, which rejects a potential interpretation of the findings in the Variable task condition of Experiment 3. Future studies that vary task load systematically will clarify the source of the reduction in blink magnitude inhibition seen in the Variable task condition of Experiment 3.

General Discussion

The present set of four experiments replicates previous reports of inhibition of acoustic blink during visual continuous performance tasks. Moreover, the present research extends these findings by showing that the same task will result in the facilitation of acoustic blink if acoustic to-be-attended stimuli are used. Taken together, the present report provides convincing evidence that attentional blink modulation during a continuous performance task is modality specific. These findings are in marked contrast to the results from trial structured experiments conducted in our laboratory that required attention to stimuli that were presented for a few seconds. Here, attention to a stimulus resulted in blink facilitation regardless of stimulus modality. Moreover, the extent of this blink facilitation could be enhanced if the task was made more difficult (see Lipp et al., 2000), whereas increased task load in the continuous performance task resulted in an increase of modality specific blink modulation, i.e., inhibition in the visual task and larger facilitation in the acoustic task.

The present results indicate that different attentional mechanisms are employed in the different types of experiments. Whereas participants in trial structured tasks that require attention to discrete stimuli employ a late selection attentional mechanism, participants in continuous structured tasks seem to rely on an early selection mechanism for optimal task performance. Evidence for the engagement of such an early selection mechanism that minimises stimulus input from non-attended stimulus modalities has not been found in any of our previous trial structured experiments – not even in very challenging reaction time tasks that were programmed to be performed at 75% accuracy. Thus, it seems that attention to continuous stimulus input is required for the utilisation of this mechanism.

The present experiments provided a demonstration of modality specific attentional blink modulation in a continuous performance task. One question to ask is whether this demonstration can help to explain the discrepancy between the results reported by Anthony and Graham (1985) and Putnam (1990) and the more recent findings reported from our laboratory or by Böhmelt et al. (1999). Anthony and Graham presented their participants, infants or college students, with foreground stimuli that lasted for five seconds at an inter stimulus interval of 5 to 17 s. Stimuli were preceded by a two second visual fixation stimulus. Thus, the interstimulus interval used in this study is shorter than the one used in the majority of the studies that failed to find evidence for modality specificity with to-be-attended stimuli that were not continuous. Moreover, the effect of modality specificity was more pronounced in infants than in adults. It may be that the utilisation of a late selection attentional style becomes more likely in adults whereas infants and children are more likely to employ an early selection attentional style. This conclusion is supported by a recent study conducted in our laboratory (Waters, 2002) that presented children aged 9-14 and adults with pictures that differed in interest. Acoustic blinks elicited at long lead intervals were larger during interesting than during dull pictures in adults, but smaller during interesting than during dull pictures in children. These findings suggest that a developmental analysis of attentional style can contribute to the clarification of the inconsistent pattern of results. The present findings have only limited relevance in relation to the data reported by Putnam (1990) as the experimental procedures employed in the studies that employed reaction time tasks were very similar.

The present results indicate that different attentional mechanisms are employed in different task settings. They do not, however, provide a full description of the conditions that will lead to the selection of one attentional style over the other. It would be very interesting indeed to characterise the boundary conditions between the task conditions that will promote one or the other attentional style. This delineation would be instructive for both, basic research on attentional processes and applied perspectives concerned with the design of work environments that rely on simultaneous input in more than one sensory modality. In the latter context it will also be instructive to determine whether it is possible to switch between attentional styles and whether it is possible to engage both simultaneously.

Figure captions

Figure 1. Blink magnitude (left panel) and latency change (right panel) during the Tracking and Stimulus only tasks in Experiment 2 as a function of lead interval (vertical bars indicate standard errors of the mean).

Figure 2. Blink magnitude (left panel) and latency change (right panel) during the Constant and Variable Tracking tasks in Experiment 3 as a function of lead interval (vertical bars indicate standard errors of the mean).

Figure 3. Blink magnitude (upper panel) and latency change (lower panel) during the Constant and Variable Tracking tasks in Experiment 4 as a function of lead interval and lead stimulus modality (vertical bars indicate standard errors of the mean).

References

Anthony, B. J., & Graham, F. K. (1985). Blink reflex modification by selective attention: Evidence for the modulation of 'automatic' processing. Biological Psychology, 21, 43-59.

Böhmelt, A. H., Schell, A. M., & Dawson, M. E. (1999). Attentional modulation of short- and long-lead-interval modification of the acoustic startle eyeblink response: Comparing auditory and visual prestimuli. International Journal of Psychophysiology, 32, 239-250.

Bradley, M. M., Cuthbert, B. N., & Lang, P. J. (1999). Affect and the startle reflex. In M. E. Dawson & A. M. Schell & A. H. Böhmelt (Eds.), Startle modification: Implications for neuroscience, cognitive science and clinical science (pp. 157-185). Cambridge: Cambridge University Press.

Braff, D. L., Geyer, M. A., & Swerdlow, N. R. (2001). Human studies of prepulse inhibition of startle: normal subjects, patient groups, and pharmacological studies. Psychopharmacology, 156, 234-258.

Graham, F. K. (1992). Attention: The heartbeat, the blink, and the brain. In B. A. Campbell & H. Hayne & R. Richardson (Eds.), Attention and information processing in infants and adults: Perspectives from human and animal research (pp. 3-29). Hillsdale, NJ: Erlbaum.

Hackley, S. A. (1999). Implications for blink reflex research for theories of attention and consciousness. In M. E. Dawson & A. M. Schell & A. H. Böhmelt (Eds.), Startle modification: Implications for neuroscience, cognitive science, and clinical science (pp. 137-156). New York: Cambridge University Press.

Hart, S. G., & Staveland, L. E. (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In H. P.A. & N. M. (Eds.), Advances in Psychology: Human mental workload (Vol. 52, pp. 139-183). New York:: North Holland Pub Co.

Hazlett, E. A., Dawson, M. E., Schell, A. M., & Nuechterlein, K. H. (2001). Attentional stages of information processing during a continuous performance test: A startle modification analysis. Psychophysiology, 38, 669-677.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1990). Emotion, attention and the startle reflex. Psychological Review, 97, 377-395.

Le Doux, J. E. (2000). Emotion circuits in the brain. Annual Review of Neuroscience, 23, 155-184.

Lipp, O. V., Neumann, D. L., & McHugh, M. J. (2003). Lead stimulus modality change and the attentional modulation of the acoustic and electrical blink reflex. Biological Psychology, 62, 27-48.

Lipp, O. V., Neumann, D. L., Pretorius, N. R., & McHugh, M. J. (2003). Attentional blink modulation during sustained and after discrete lead stimuli presented in three sensory modalities. Psychophysiology, 40, 285-290.

Lipp, O. V., Siddle, D. A. T., & Dall, P. J. (1998). Effects of stimulus modality and task condition on blink startle modification and on electrodermal responses. Psychophysiology, 35, 452-461.

Lipp, O. V., Siddle, D. A. T., & Dall, P. J. (2000). The effects of warning stimulus modality on blink startle modification in reaction time tasks. Psychophysiology, 37, 55-64.

Neumann, D. L. (2002). Effect of varying levels of mental workload on startle eyeblink modulation. Ergonomics, 45, 583-602.

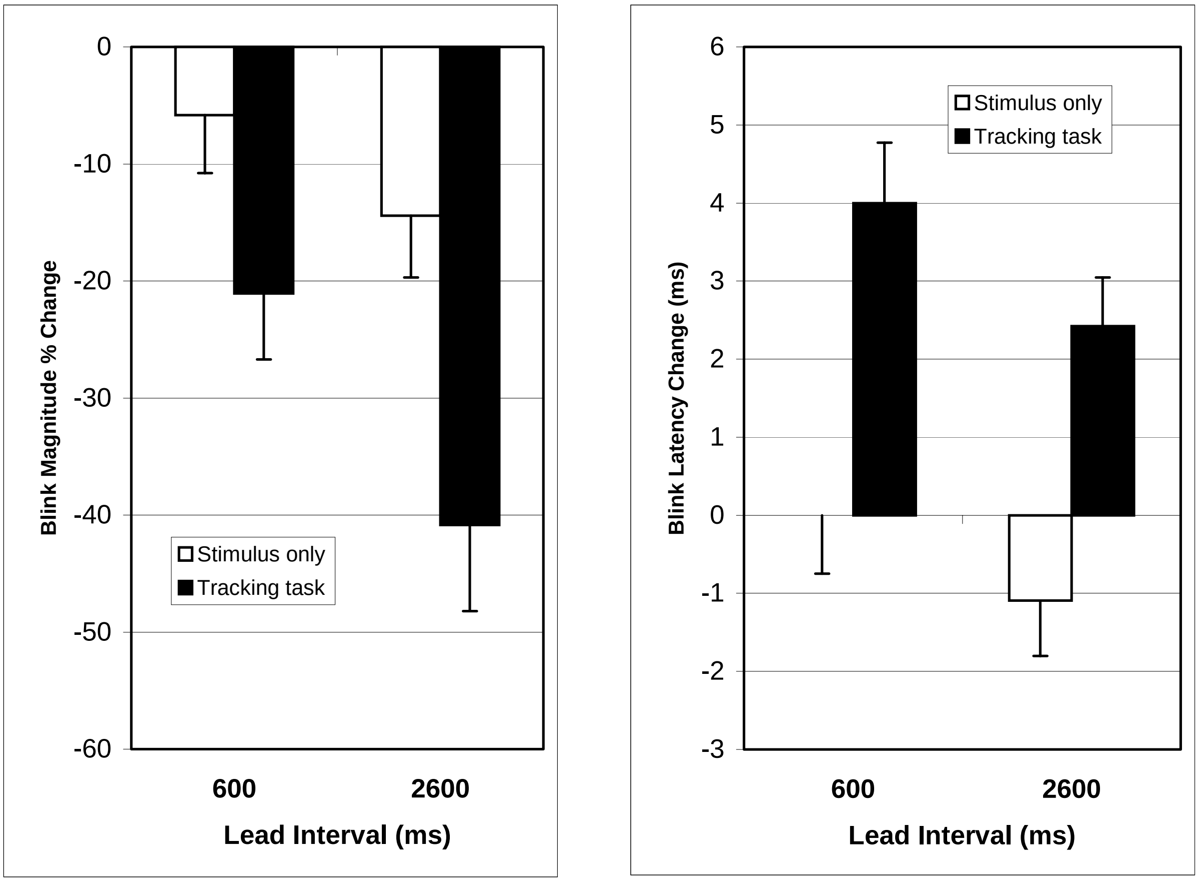
Putnam, L. E. (1990). Great Expectations: Anticipatory responses of the heart and brain. In J. W. Rohrbaugh & R. Parasuraman & R. Johnson, Jr. (Eds.), Event related brain potentials (pp. 178-209). New York: Oxford University Press.

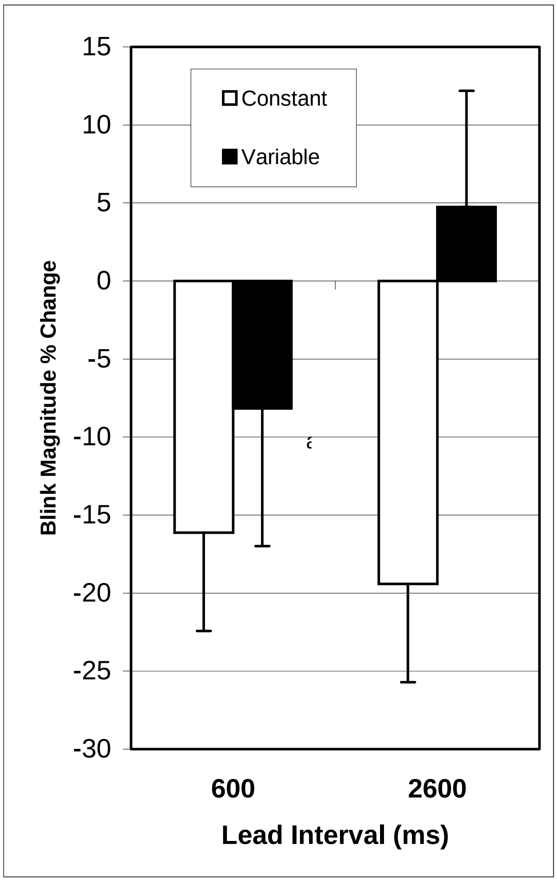
Putnam, L. E., & Vanman, E. J. (1999). Long lead interval starle modification. In M. E. Dawson & A. M. Schell & A. H. Böhmelt (Eds.), Startle modification: Implications for neuroscience, cognitive science, and clinical science (pp. 72-92). Cambridge, UK: Cambridge University Press.

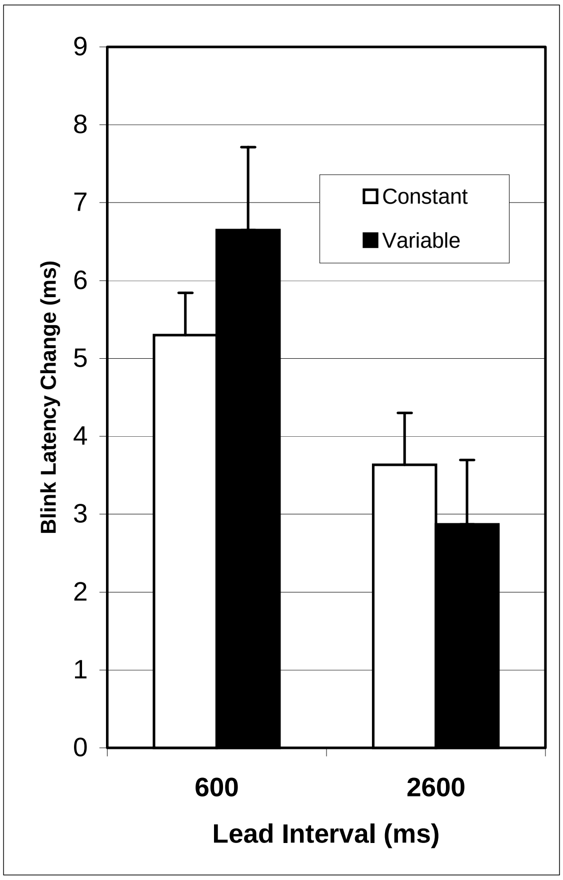
Rohlf, F. J., & Sokal, R. (1981). Statistical tables. New York: Freeman.

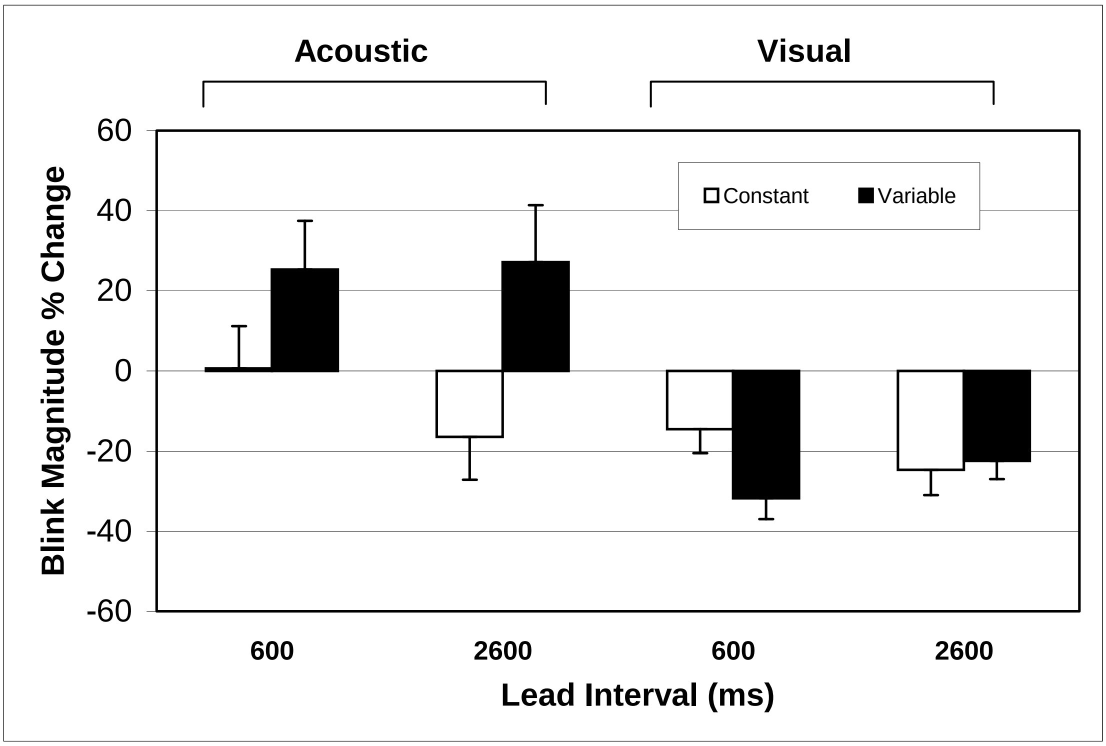
Waters, A. M. (2002). An investigation of processing bias in childhood anxiety disorder. Unpublished Doctoral Dissertation, University of Queensland, Australia.

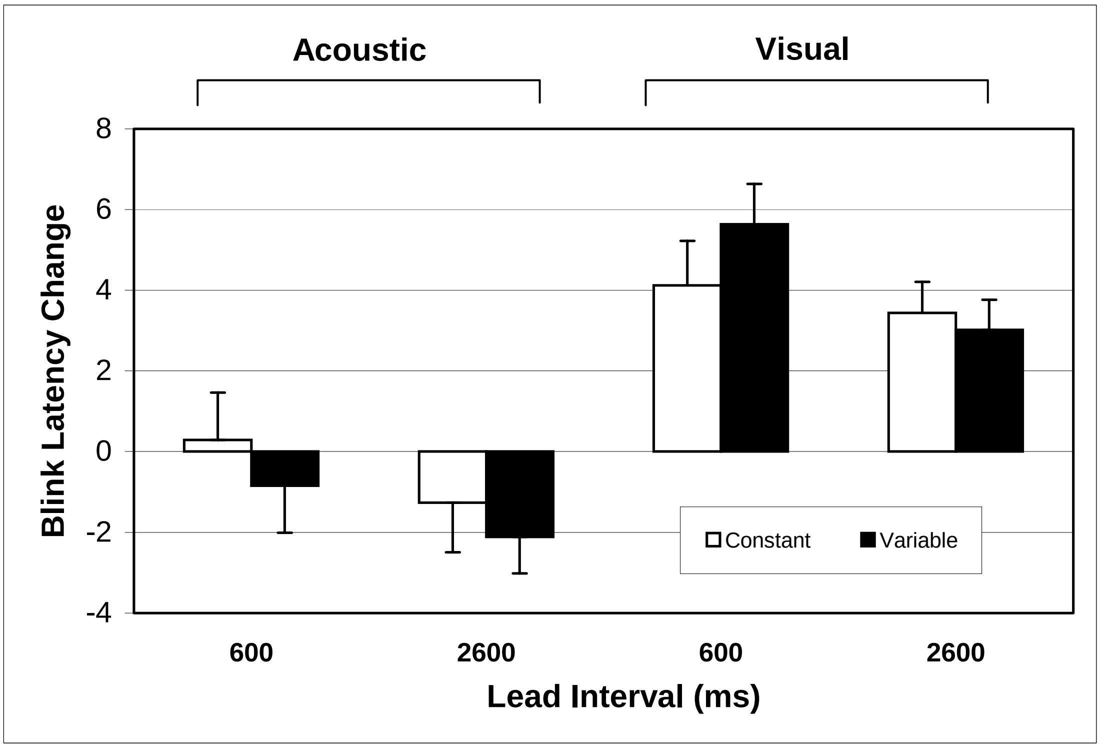
Wierwille, W. W., & Casali, J. G. (1983). A validated rating scale for global mental workload measurement applications, Proceedings of the Human Factors Society 27th Annual Meeting (pp. 129-133). Santa Monica, CA: Human Factors Society.


Blink Magnitude % Change
0
-10
-20
-30
-40
-50
-60
□ Stimulus only
■ Tracking task
600
2600
Lead Interval (ms)
Blink Latency Change (ms)
6
5
4
3
2
1
0
-1
-2
-3
□ Stimulus only
■ Tracking task
600
2600
Lead Interval (ms)


15
10
5
0
-5
-10
-15
-20
-25
-30
Blink Magnitude % Change
☐ Constant
■ Variable
600
2600
Lead Interval (ms)


9
8
7
6
5
4
3
2
1
0
Blink Latency Change (ms)
☐ Constant
■ Variable
600
2600
Lead Interval (ms)


Acoustic
Visual
60
40
20
0
-20
-40
-60
Blink Magnitude % Change
□Constant
■Variable
600
2600
600
2600
Lead Interval (ms)


Acoustic
Visual
8
6
4
2
0
-2
-4
Blink Latency Change
□Constant
■Variable
600
2600
600
2600
Lead Interval (ms)