Using a More Intuitive Cue in a Temporal Attention Discrimination Task to Compare Endogenous and Exogenous Mechanisms

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Abstract

Temporal attention is a cognitive mechanism that allows individuals to prepare to respond to an anticipated event. Lawrence and Klein (2013) distinguished two forms of temporal attention: one elicited by purely endogenous alerting mechanisms, and one elicited through exogenous alerting mechanisms. Recently, McCormick et al. displayed that these mechanisms generate additive effects on reaction time, however more informative speed and accuracy comparisons were not possible due to them being measured during a detection task. The current pair of experiments looks to compare these two forms of temporal attention in a discrimination task while measuring both speed and accuracy, by inducing methodological modifications that lower task demand. These manipulations were successful, as temporal cueing effects were observed for both the combined form and the less-studied purely endogenous form. However, speed-accuracy performance for these two forms of temporal attention did not align with our predictions based on Lawrence and Klein (2013), leading us to speculate on the generalizability of their results.

INTRODUCTION

Posner and Petersen popularized the three-component model for attention, comprising alerting, orienting, and executive functioning (1990). These three components are anatomically distinct and contribute different attentional functions. Alerting generates and maintains arousal. Orienting focuses attentional resources to increase perception. Executive functioning filters information to ensure an individual can focus attention on relevant information (Posner & Petersen, 1990). Expanding upon this taxonomy, Klein and Lawrence (2012) have proposed consideration of ‘domain of allocation’ and ‘mode of allocation’ across these previously outlined mechanisms (see figure 1). *Domain* refers to whether attention is allocated in space, time, or task. *Mode* refers to whether attention is elicited exogenously or endogenously. Exogenous elicitation is bottom-up and a reflexive response to salient stimuli. Endogenous elicitation is top-down and typically established through learned contingencies between paired stimuli (Klein & Lawrence, 2012). By adding these distinctions, researchers can more clearly delineate how attentional mechanisms impact performance under a variety of conditions.

		Mode of Allocation	
		Exogenous or bottom-up	Endogenous or top-down
Domain of Allocation	Space	Capture	Expectancy
	Time	Alertness	Preparation
	Task	Instinct/Habit	Allocation

Figure 1: Klein and Lawrence’s extended taxonomy for attention, including mode and domain of allocation.

Alerting

As mentioned, alerting refers to the generation and maintenance of arousal. There are, however, two different alerting types: *tonic* and *phasic*. The main differentiating feature between these two types is the time-course in which it affects an individual. Tonic alerting occurs across a longer time span. For instance, tonic changes in arousal throughout the day are typically aligned with circadian rhythms (Posner, 1975). Phasic alerting, in contrast, typically increases arousal on a scale of seconds in response to some event. When a phasic alerting response is elicited, it is associated with increased activity in the locus coeruleus, an area that produces norepinephrine (Aston-Jones & Cohen, 2005). This has been shown to result in decreased response speed without affecting the rate of information processing (Posner, Klein, Summers, & Buggie, 1973; McCormick, Redden, Hurst, & Klein, 2019). Because the rate of information processing, which is what allows participants to make judgements about task-related events, is unaffected during a phasic alerting response, participants may be responding with a lower amount of information present (or, a lower threshold for generating a response). The relation between response speed and processing speed is important to consider in relation to alerting, as increased arousal does not necessarily generate improved performance as it may reflect a trade-off between the speed and error rate (Wicklegren, 1977).

There is a significant body of work outlining the distinctions between endogenous and exogenous orienting in the spatial domain (Klein, 2009). Notably, this research indicates that these two modes of spatial attention recruit different neural mechanisms and affect performance differently, providing evidence for the importance of including this distinction in the taxonomy of attention (Klein & Lawrence, 2012). Until recently, research in the domain of alerting, which has also been conceptualized as a form of orienting in the temporal domain (Kingstone, 1992), largely lacks this distinction due to typical confounding endogenous and exogenous control (Lawrence & Klein, 2013, but see Rohenkohl, Coull & Nobre, 2011, for a related effort). When attempting to study the effect of exogenous alerting on task performance, researchers manipulate signal intensity and observe a positive relationship with response speed (as intensity increases, response speed decreases; Loveless & Sanford, 1975; Niemi, 1982). Manipulations of signal intensity include changing decibel level, signal duration, and the interval between the signal and the target being presented. However, researchers have typically confounded exogenous with endogenous alerting. Participants quickly learn that the presentation of a signal means a target will soon be presented. This learned association allows for participants to *volitionally* (endogenously) prepare for the presentation of a target based on a signal. One method that has been used to try to limit the influence of endogenous components is implementing a *'non-aging foreperiod'* (Nickerson & Burnham, 1969). A non-aging foreperiod is an exponential distribution of stimulus onset asynchronies (SOAs) across trials so that participants do not know how long of an interval there will be between a warning signal and target. However, the consistency in which stimuli are presented in a particular order, whereby signals always predict that a target is next in sequence, allows for the recruitment of endogenous mechanisms even though this method minimizes the possibility of precise anticipation of stimuli (Lawrence & Klein, 2013). Similarly, studies that attempt to isolate endogenous temporal attention typically use a signal that reflexively alerts participants in some way by increasing in intensity, whether that be through an increase in volume (auditory warning signal), brightness (visual warning signal), or stimulation (tactile warning signal), thus confounding the endogenous temporal mechanisms.

For these reasons, Lawrence and Klein (2013) developed a novel methodology to better isolate these two forms of temporal attention, and to observe how they may differently impact human performance. They utilized Rescorla's (1967) 'truly random procedure' to minimize the possibility of eliciting endogenous mechanisms. This procedure, which was developed for research on animal learning, involves presenting signals and targets independently of one another. In such a non-contingent design, signals (S) and targets (T) can occur in any pattern (ex: T-T-S-T-S-S-S), thus minimizing the possibility of any learned contingencies between these stimuli. In contrast, a contingent design presents signals and targets in a predictable pattern, so that the presentation of a signal reliably indicates the next event will be a target (ex: S-T-S-T-S-T). For non-contingent designs, analysis involves retrospectively parsing the data to identify instances where the signal was presented before the target for analysis. This reduces the influence of top-down processes and allows researchers to independently observe the effect of exogenous alerting.

To mitigate the influence of exogenous mechanisms during the study of endogenous mechanisms, Lawrence and Klein also developed a dichotic signalling technique. Participants are presented with diotic, or mono (correlated to each ear), white noise through a pair of headphones throughout the experiment. This means the same static frequency is played in each ear. The presentation of the signal involves a temporary (100ms) shift from *diotic* to *dichotic* (stereo; uncorrelated sound to each ear) sound. This allows for a subjectively salient auditory event which does not entail an increase in intensity, analogous to an isoluminant colour-change (Lawrence & Klein, 2013). In doing so, participants have the ability to volitionally prepare for upcoming stimulus events, while minimizing the influence of exogenous alerting.

By manipulating contingency and intensity conditions, Lawrence and Klein were able to compare how these two mechanisms differently impacted performance (see Figure 2).

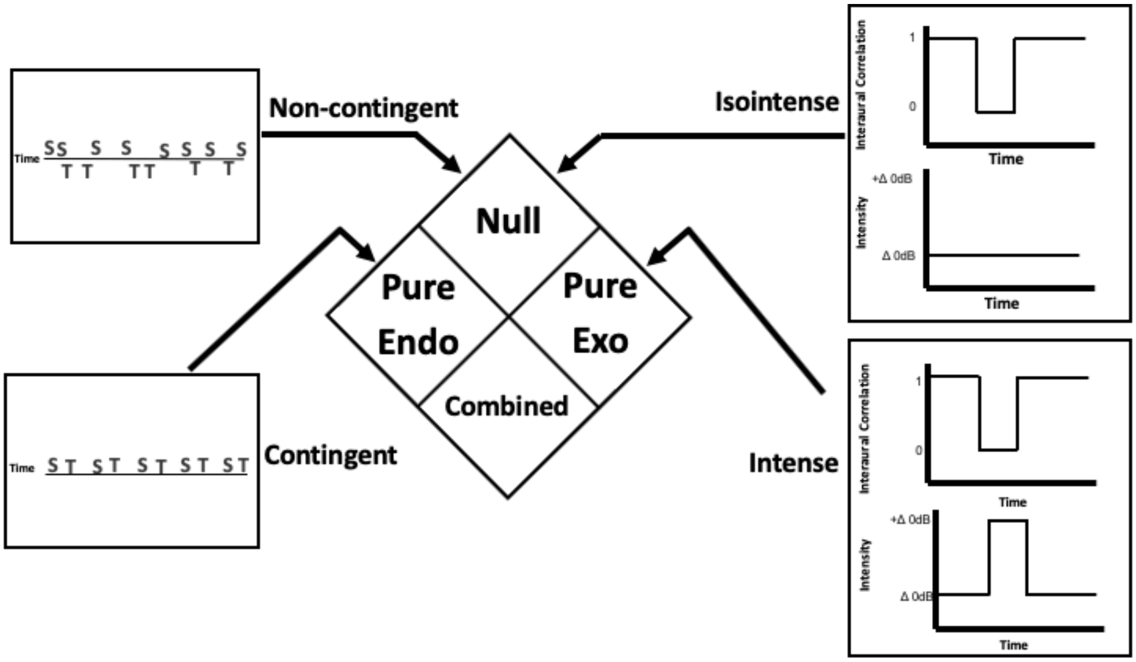

Figure 2: A breakdown of the different possible combinations in Lawrence and Klein's experimental design. The two contingency manipulations (contingent, noncontingent) are outlined on the left, and the two signal intensity manipulations (isointense, intense) are outlined on the right. Image redrawn from Lawrence and Klein, 2013.

A 'purely endogenous' condition involves a contingent design with isointense signals, because participants can prepare using the predictive nature of the signal without it eliciting reflexive alerting. A 'purely exogenous' condition involves a non-contingent design with intense signals, as differences in performance will solely come from reflexively generated alerting. A 'combined' condition involves a contingent design with intense signals, eliciting mechanisms related to both exogenous and endogenous temporal attention. It is worth noting that the 'combined' condition is representative of most research exploring temporal attention, as temporal cue stimuli are predictably presented before targets using a signal that involved an increase in intensity (Weinbach & Henik, 2012). A 'null' condition involves a non-contingent design with an isointense signal. This null condition produced the poorest reaction time and accuracy performance of these intensity and contingency combinations, as the stimuli are non-predictive and do not increase in intensity, so it does not reliably recruit endogenous or exogenous temporal mechanisms. The two pure alerting conditions are compared to this null condition, as they either add intensity (purely exogenous) or contingency (purely endogenous) to the observer performing the task. Purely exogenous alerting improved reaction times without any cost to accuracy (Figure 3, Pure Exo). Purely endogenous alerting improved both reaction time and accuracy (Figure 3, Pure Endo). In the combined condition (Figure 3, Combined), which elicits both forms of temporal attention, a speed-accuracy trade-off was observed in comparison to the purely endogenous condition. These two are compared because the only difference in design is the addition of intensity in the combined condition. This means a decrease in reaction time was met with a concomitant increase in error rate.

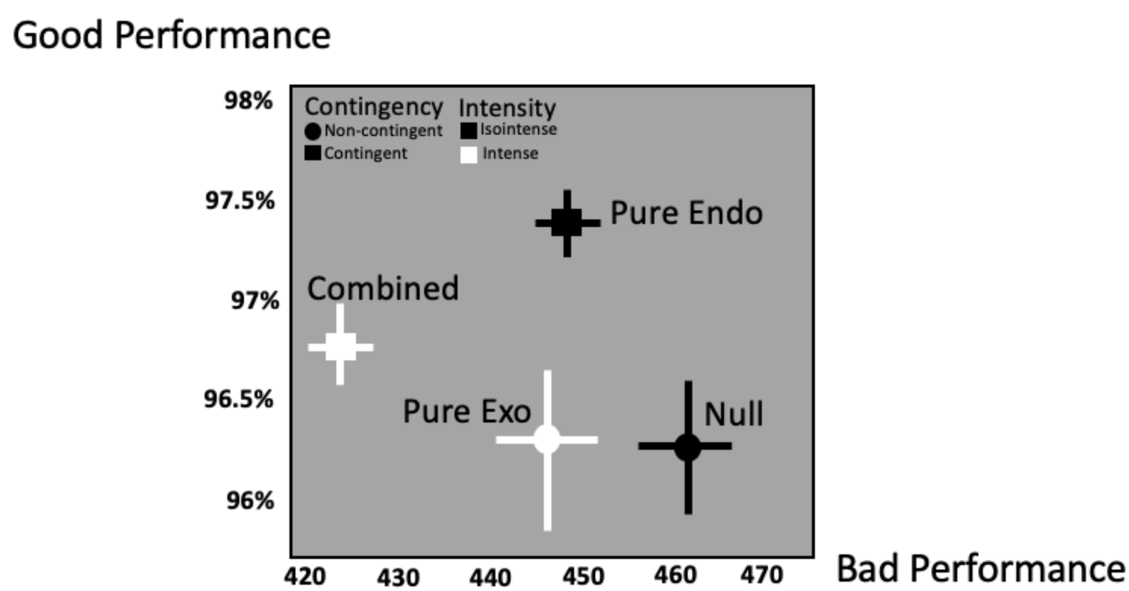

Figure 3. The redrawn results from Lawrence and Klein (2013) mapped in speed-accuracy space. A = the purely exogenous condition, B = purely endogenous condition, C = the combined condition, D= the null condition. Performance is best in the top left-hand corner (fast and accurate) and worst in the bottom right-hand corner (slower and less accurate). The error bars are 95% confidence intervals for both RT (horizontal) and accuracy (vertical).

As reported by the authors, this was the first evidence of 'separable, but interactive modes of exogenous and endogenous temporal attention' (page 567, 2013), an important step for furthering the research of dissociable mechanisms in temporal attention.

Temporal Cueing and the Kingstone Paradigm

Temporal cueing (or 'temporal orienting') is the focusing of attentional resources to a particular interval based on information provided by a cue. Kingstone introduced a paradigm to study this cognitive mechanism in 1992 (although typically attributed to Coull & Nobre, 1998). In a five-part experiment, he studied how visual cues for various target qualities and modalities may interact with one another. In Experiment Four, participants received a cue to indicate the likely target form (cues were 1 and 2 to predict 'A' or 'V' letter stimuli, respectively) and a temporal cue which indicated *when* a target was likely to occur (cues were 'S' and 'L' to predict a short [400ms] or long [1600ms] interval). Both of these cue types were 80% predictive. The temporal cue is analogous to the seminal spatial cueing paradigm developed by Posner (1980). Participants were faster when presented with valid temporal cues compared to invalid temporal cues, which was later defined as a temporal cueing effect (Correa et al., 2004). Using a slightly modified two-cue Kingstone paradigm, Coull and Nobre (1998) compared neural correlates of spatial and temporal cueing. One cue identified the likely spatial location, and the other identified the likely temporal interval. One set of participants completed the study with PET recording, and another with fMRI recording. Behaviorally, as previously reported (Kingstone, 1992), the two forms of cues elicited similar valid-cue advantages in response time. Although, there was a significant amount of overlap between the different brain areas involved in spatial and temporal cueing, temporal attention activated the left intraparietal sulcus and left inferior premotor cortex, while spatial attention activated the right intraparietal sulcus, implying a neural distinction between spatial and temporal attention.

Since these early temporal cueing studies, temporal attention has become a burgeoning field. In this time, four distinct types of temporal attention have been recognized and categorized (see Nobre & van Ede, 2018, for a complete review). Our references to temporal cueing will be related to temporal associations, involving the use of symbolic temporal cues. Temporal cueing improves reaction time performance in both discrimination and detection tasks (Correa et al., 2004). While the study of reaction time has been important for understanding temporal cueing, studies typically neglect discussing error rate. This is potentially due to the typical ‘non-significant’ finding when running ANOVAs[1], or due to the precedent that has been set due to past published research in the field (see table 1).

[1] ANOVAs are a common form of analysis in the field of temporal cueing, although it is not appropriate for the binomial distribution that correct/incorrect error rate generates.

Table 1

Temporal cueing effects (invalid - valid) and Error Rates of past temporal cueing research. An asterix (green fill) indicates a significant effect

Study	Condition	Temporal Cueing Effect	Valid Cue Error Rate	Invalid Cue Error Rate
Kingstone 1992 (Exp4)	Only Temporal Cue (discrimination)	21ms*	7.2%	4.9%
	Expected Target Form (discrimination)	38ms*	5.7%	5.2%
	Unexpected Target Form (discrimination)	-33ms *	5.9%	5.7%
Coull and Nobre (1998)	Temporal Detection Task	48ms*	NA	NA
Correa, Lupianez, Milliken, and Tudela (2004)	Detection w/ colour cue	26ms*	NA	NA
	Discrimination w/ colour cue	-2ms	1.68%	4.64%
	Discrimination w/ colour cue (within block TE)	12ms	4.04%	4.12%
	Discrimination w/ line cue (within block TE)	13ms	3.57%	3.62%
	Discrimination w/ colour cue (between block TE)	83ms*	2.86%	2.46%
	Discrimination w/ line cue (between block TE)	93ms*	2.81%	2.46%
McCormick, Redden, Lawrence, and Klein (2017)	Mixed Signal Intensities: Intense (discrimination)	6ms	8%	7%
	Mixed Signal Intensities: Isointense (discrimination)	1ms	8%	10%
	Blocked Signal Intensities: Intense (discrimination)	9ms	7%	5%
	Blocked Signal Intensities: Isointense (discrimination)	3ms	6%	7%
McCormick, Redden, Lawrence, and Klein (2018)	Mixed Signal Intensity: Intense (detection)	14ms*	NA	NA
	Mixed Signal Intensity: Isointense (detection)	15ms*	NA	NA

Error rate is an important metric for understanding whether temporal attention is generating pure improvements to performance, or whether it is improving speed at the cost of accuracy. In spite of the underreporting, there is still evidence from a variety of alternative metrics that temporal attention may improve both motor preparation and perception, depending on the demands of the task. In studies in which only a detection response is required, physiological measures suggest increases in only motor preparation (Coull & Nobre, 1998; Griffin, Miniussi, & Nobre, 2002; Correa, Lupianez, Tudela, 2005), whereas studies which require a perceptual discrimination implicate increases in both motor preparation and perceptual processing (Correa, Lupianez, Tudela, 2005; Davranche, Nazarian,Vidal, & Coull, 2011; Denison, Heeger, & Carrasco, 2017; Fernández, Denison, & Carrasco, 2019). Additionally, temporal cueing has been shown to increase fixation stability at the likely target interval, which is theorized to be a mechanism for improving perception (Denison, Yuval-Greenberg, & Carrasco, 2019). The allocation of perceptual resources at these specific time-points has been shown to produce a trade-off of perceptual clarity in the moments before and after the expected stimulus presentation (Denison, Heeger, & Carrasco, 2017). Temporal cueing effects have been found both within and across-modalities in cue-target paradigms (Lange & Roder, 2006).

Revising the Kingstone Paradigm

Although there have been great strides in recent decades related to the study of temporal attention, there are sound criticisms of some of the standardized methodological decisions. In a review titled ‘Temporal orienting and alerting: the same or different?’ Weinbach and Henik (2012) outline how the Kingstone cueing paradigm is confounded by exogenous alerting. As explained previously, temporal orienting cues tell participants the likely SOA in which a target will be presented. Moreover, the cue additionally indicates that the SOA has begun, thus indicating to participants to start their internal timers. These cues traditionally involve an increase in intensity, whether it is visual (brightness) or auditory (sound). As salient stimuli typically induce a reflexive alerting response, it is not possible to observe a pure effect of endogenous temporal cueing with this methodological design. McCormick et al (2018) designed a modified Kingstone cueing paradigm to address this issue. Participants were presented with the temporal letter cue at the beginning of the trial, instead of at the start of the indicated temporal interval, and this remained on the screen until the target was presented. This cue, which was either an ‘S’ to indicate a ‘short’ interval (400ms), or an ‘L’ to indicate a ‘long’ interval (1600ms) as in Kingstone (1992), informed participants of the likely SOA that the target would be presented. Then, after a random interval (between 2 and 10 seconds), an auditory signal was presented to inform participants to ‘start their interval clocks’ to the cued interval. As in Lawrence and Klein (2013), this signal entailed a switch from diotic to dichotic white noise, which allowed for the comparison of intense and isointense signals. Intense signals, which increased in dB, represented a replication of the previous work in the field, whereas isointense signals provided a novel opportunity to study purely endogenous temporal orienting. This new design de-confounds the relationship between alerting and temporal orienting, and also separates the circumstance wherein temporal cues both inform participants of the interval and operate as the start-timer signal (see Figure 4).

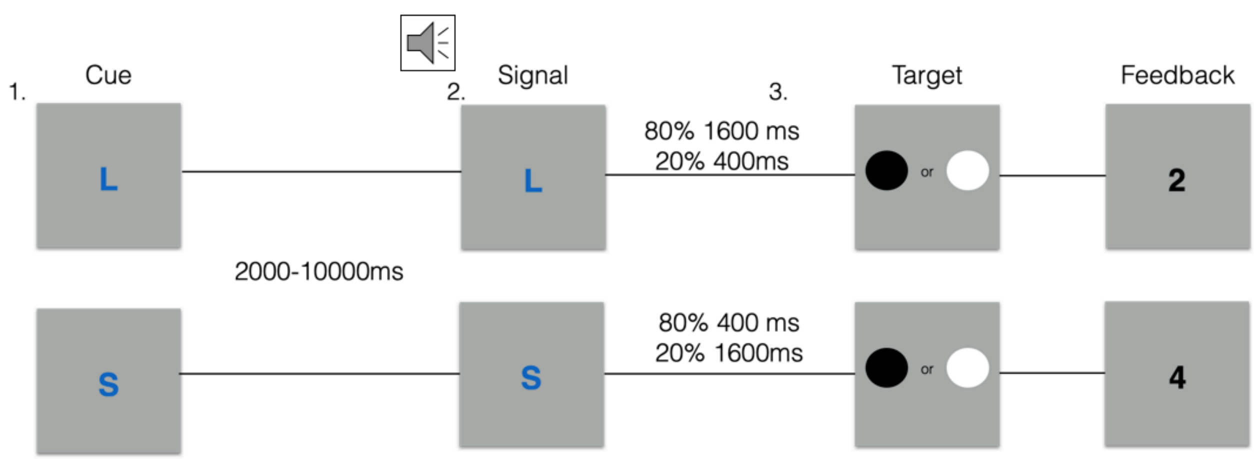

Figure 4. Design for McCormick et al. 2018. Section 1 of the figure displays the two different temporal cue types. These letters indicate whether a short (400ms) or long (1600ms) SOA will take place between the signal and target, with 80% accuracy. These cues remain on the screen for a 2000-10000 msec period. Then, a signal is played, either intense or isointense, which indicates participants should initiate their ‘internal timer’ to the indicated interval (section 2). Then, either the short or long SOA occurs, before the presentation of the target (section 3). Participants are then provided with RT feedback in the form of a single digit.

Two previous design attempts with this novel methodology were described in the introduction of McCormick et al (2018; see also McCormick, Redden, Lawrence, & Klein, 2017). In the first experiment, signals were intermixed within-blocks, so participants did not know whether they would be presented with an intense or isointense signal on a given trial. In this version, participants were required to discriminate between two possible targets. There were no significant temporal cueing effects in either signal condition (see Figure 5 ‘within-block’). This was perplexing, as the intense signal condition was a replication of the combined alerting type used by past temporal cueing studies. In Experiment Two, participants still made discrimination responses, but signals were presented between blocks. This meant that participants would know which signal type they were going to receive for the entire block of trials. In this version, there was evidence of cueing effects in the intense signal condition, in which valid temporal cues generated faster RTs than invalid temporal cues, but there were no temporal cueing effects present in the isointense signalling condition (see Figure 5 ‘between-block’). This meant we replicated an analogous condition to the previous temporal research but did not observe the expected effects in the purely endogenous condition.

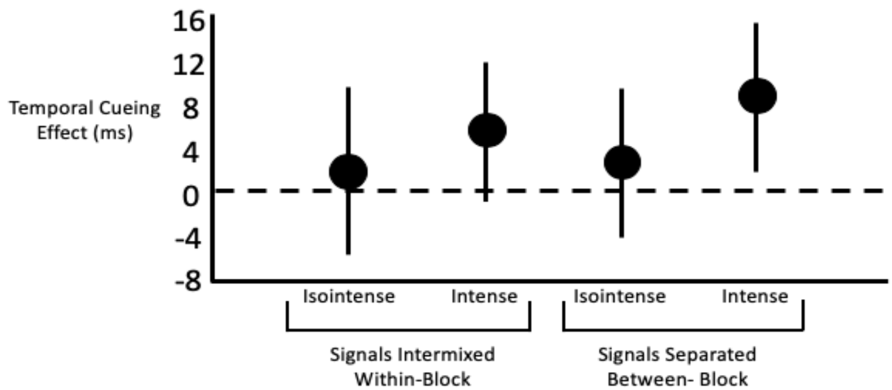

Figure 5. Redrawn from McCormick, Redden, Lawrence, and Klein, 2018. This displays the effect size of the temporal cueing effect (in ms) for each of the signalling conditions across two experiments. Error bars are 95% confidence intervals.

We hypothesized that the amount of mental effort required to detect the isointense warning signal may have interfered with an observer's ability to effectively make use of the temporal cue. More explicitly, when in the block with both types of signals, participants are uncertain of what intensity the signal will be. This motivates them to consistently enlist sufficient effort to detect an isointense signal (thus occupying similar levels of limited cognitive resources regardless of signal type), which results in non-significant cueing effects for both intensity conditions. This hypothesis is also strongly supported by observing cueing effects when there are only intense signals, and no effects when there are only isointense signals — conditions wherein observers can contextually modulate the amount of effort needed to detect the warning signal. Based on this hypothesis, we decided to replicate this experiment while reducing overall cognitive load in an attempt to observe temporal cueing effects in both signalling conditions. In

McCormick et al. (2018), participants completed a *detection* task where both signal types were intermixed within-block. Our intention of using a detection task (rather than discrimination which was used in the previous experiments) was to lower the cognitive demands associated with the primary response task—in the expectation that with this lower demand, participants would have sufficient residual cognitive capacity to utilize the predictive temporal cues regardless of signal intensity. Using this detection task, we were effectively able to produce a temporal cueing effect in both signalling conditions, presenting the first demonstration of a temporal cueing effect in a purely endogenous condition. Additivity was observed for but reaction time and reaction time variance. Thus, using Sternberg's additive factors logic (1969), we inferred that these two forms of temporal attention, with the exogenous form generated by the intense versus iso-intense signals and the endogenous form generated by valid versus invalid Kingstonian cuing, were affecting independent stages of processing.

Because this previous experiment used a detection task, as opposed to a discrimination task, there was only reaction time data to compare signalling conditions. In the information processing theory of phasic alertness, Posner (1975) concluded that alerting impacts the time in which a participant will respond to a stimulus but have no effect on the build-up of information. For this reason, accuracy measures are essential for properly studying the mechanisms of interest. The contrast of the speed-accuracy relationships of these two independent mechanisms is needed to properly categorize and utilize them. It would also allow for a comparison to the results from Lawrence and Klein (2013), who showed different speed accuracy relationships between their different conditions (see Figure 3). They used a different design than the Kingstone paradigm, as participants were only ever cued to one interval during a block as opposed to flexibly switching trial-by-trial, so it is of interest whether the performance across the two studies will align, or whether we shall generate a new pattern. Additionally, measuring accuracy during this temporal cueing task would potentially shed light on whether temporal cueing is facilitating the motor response, which allows for participants to respond faster, or whether it is also improving perception at the indicated interval, as has been implied by past research (Denison, Heeger, & Carrasco, 2017).

It is clear that to make a more comprehensive comparison of performance between signalling conditions in this temporal cueing paradigm, a discrimination task must be used. However, our previous work (see p. 14, McCormick et al., 2018) we discovered that combining the the modified Kingstone paradigm with the iso-intense signals imposed a cognitive load that interference with the endogenous use of the temporal cues. Thus, a further simplification of our temporal cueing paradigm is needed if we are to generate and measure endogenous temporal attention.

EXPERIMENT ONE

This experiment uses McCormick et. al.'s modified Kingstone paradigm to compare performance between two forms of temporal cueing (2018). This involves using intense and isointense signals to inform participants when to implement the temporal information provided by the cue. Instead of using letter cues to inform participants of when the target is likely to occur, we will be using two different line cues. The length of these lines will be representative of the temporal intervals and is meant to be more intuitive. Correa et al. has successfully used these as temporal cues in past research (2004). If a '--' cue is presented, this means that it is likely going to be a short SOA between the auditory signal and the target. If a '--------' cue is presented, this means that it is likely going to be a long SOA between the auditory signal and the target. These are scaled appropriately, as the 'short' SOA for this experiment is 400ms (two hyphens) and the 'long' SOA is 1600ms (eight hyphens). Where we predict these cues may be more intuitive to interpret trial-by-trial than the Kingstonian letter cues, this should free up cognitive resources previously usurped by less intuitive cues. With more capacity available temporal cueing effects ought to be elicited in both signalling conditions, thus allowing for a comparison of speed and accuracy between these two intensity conditions. If we are successful, this would be the first-time temporal cueing effects were observed in a discrimination task using a purely endogenous temporal cueing manipulation. In that case, we would expect valid temporal cues to produce faster reaction times than invalid temporal cues in both signalling conditions. We also expect that intense signals will produce faster responses than isointense signals due to their ability to elicit exogenous alerting. Importantly, this design will allow for the comparison of error rates, for which we predict that the combined (intense signals) condition will produce less accurate responses than the purely endogenous (iso-intense signals) condition. By addressing these hypotheses, we will be investigating the original unanswered questions associated with our two recent studies (McCormick et al. 2017; 2018). This experimental design will also provide the opportunity to compare our two signalling outcomes to Lawrence and Klein's (2013) mapping of exogenous and endogenous alerting performance to assess the generalizability of their conclusions.

Method

Pre-registration

This experiment was on the Open Science Framework (OSF) prior to the observation of any participant data. This registration includes description of hypotheses, methodology, and analysis plans. All associated project materials can be found on this project's OSF page (https://osf.io/dexsm).

Participants

Forty-eight participants were run in this experiment in a computer laboratory. Data collection sessions involved a maximum of 10 participants at a time. Sessions were run until 40 or more participants met our trial count criterion. Prior research using this methodology has found detectable effects with 40 participants (McCormick et al., 2018; McCormick et al., 2017), which was our rationale for setting this criterion. All participants were undergraduate students at Dalhousie University. All participants had normal or corrected-to-normal vision and hearing. Further information on participants and the trial count criterion is provided in the results section.

Apparatus

This experiment was presented on ten 24-inch Apple monitors connected to a Mac Mini running OS X with a 2.66 GHz Intel Core 2 Duo processor and a NIVIDIA GeForce 9400 256 MB graphics card. A set of 10 headphone monitors (Sony MDR- 101LP) were used. The acceptable volume setting was Level Four on the Mac volume interface. This volume was pre-set for participants, and they were instructed to inform the experimenter if it was too loud or quiet. If the experimenter was alerted that the volume was not appropriate, they made note of this and adjusted accordingly. Participants sat at a maximum distance of 102 cm from the screen (i.e., the length of the headphone cord). Game-pad controllers (Xbox 360 wired controllers; Microsoft

Corp, 2006) were used by participants to make responses using the gradient triggers located under their index fingers.

Stimuli

Temporal cues, which could take the form of either a short line (--) or long line (--------) (? or.5 degrees of visual angle, respectively; DVA) were presented at the center of the screen until the presentation of the target. These cues were blue (RGB: 0, 0, 255) on a gray (RGB: 119, 119, 199) background. Targets took the form of circles (.5 DVA) that appeared at the center of the screen. Targets were either black (RGB: 0, 0, 0) or white (RGB: 255, 255, 255). Participants received on-screen feedback in the form of a single black or white number (.5 DVA) after making their response. The number represented their reaction time on that trial in 10ths of a second, and the colour represented which of the two buttons they had selected. Mono auditory white noise (generated by Python program) was constantly presented throughout a trial at a sampling frequency of 44100 Hz. Auditory warning signals were presented in the form of stereo (uncorrelated) white noise for a duration of 100 ms. In the ‘isointense’ warning signal condition, there was no change in intensity relative to the mono baseline. In the ‘intense’ warning signal condition, the ambient volume was doubled for this short duration.

Procedure

Participants were accurately instructed that the temporal information provided by cues would help optimize performance as the cues indicated with high probability (80%) whether the foreperiod between the auditory warning signal and the target would be short (400ms) or long

(1600ms). They were also informed that there were two types of auditory signal that would be presented before the target, and that both should be used to prepare for the upcoming target. An emphasis on speed was communicated to participants. A practice block was conducted consisting of 40 trials that were not included in the analysis. Mono noise was presented in both ears continuously throughout the task. Trials began with a blue line which represents a probable 400 ms or 1,600 ms foreperiod between the later auditory warning signal and the presentation of the target, respectively. The temporal cue remained on-screen until the target was presented. The auditory warning signal was presented after a random exponential (i.e. non-aging) interval within the range of 2 to 6 seconds (mean = 4 s) to indicate the target was imminent. The auditory warning signal was either an intense or isointense shift from mono to stereo sound and was presented for a duration of 100 ms. Either 400 or 1,600 ms after the onset of this auditory signal, a black or white target was presented for either 1,000 ms, or until the participant responded. Discrimination responses were made by pressing one of the triggers on the gamepad. If it was a white circle target, participants were instructed to press the right trigger. If it was a black circle target, participants were instructed to press the left trigger[2]. Participants were instructed that they were required to press the response apparatus at least halfway down to register a response. If participants responded before the target was presented, then a message that read ‘Too Early!’ was presented in red (RGB: 255, 0, 0). If they failed to respond during this 1,000 ms window, then a message that read ‘Miss!’ was presented in red. If participants responded during the correct

[2] Although target colour, which was confounded with responding hand (white=right), was not considered an important factor, it is worth noting that responses to white targets were about 15 ms faster than to black targets in both experiments. Because this was also true for the few left-handed participants that were collected (n=4), it is not believed that this is due to hand dominance. Instead, the relative salience of the white targets on the grey background was greater than that of the black targets. Importantly, the target factor did not interact with temporal cuing and its effect has been ignored.

window, they were presented with a number on the screen that represented their time in tenths of a second. This experiment has 40 trials per block, with 12 blocks in total.

Results

Data Preprocessing

First, we used a number of recorded metrics to eliminate inappropriate responses from the reaction time data. Pre-target responses (2.3%; 571 trials) were removed, along with <.1% (4 trials) of inter-trial responses. Trials were eliminated because the participant pressed both triggers (6.0%; 1622 trials), and when participants initiated one response and switched to another (4%; 1007 trials). Participants missed responses on 117 trials, which were removed. There were <.1% of trials (14 trials) in which participants did not reach the indicated gradient threshold on the trigger key.

The relationship between reaction time and error rate was then used to determine appropriate distribution cut-offs for this data-set. This procedure has been successfully used in prior research (Christie et al., 2015; McCormick et al., 2019), and provides a non-arbitrary procedure for excluding RTs that may not truly reflect the speeded information processing our task was designed to elicit. These cut-offs were made before performing any statistical analysis and are explained in our OSF registration (https://osf.io/dexsm). Inspection of the error rates for the faster end of the reaction time distribution informed us of the fastest time in which participants were actually able to discriminate between targets, and we only included data that indicated participants were responding greater than chance (greater than 60% accuracy, with enough trials to believe that this accuracy was a valid representation of performance). We binned reaction times in intervals of 50ms (0-50 ms, 50-100 ms, 100-150 ms, etc.) to compare accuracy and frequency of responses. At the faster end of responses, an increase in accuracy and frequency was observed at 200ms (150-200 ms: 59.1% accuracy, 22 trials; 200-250 ms: 65% accuracy, 207 trials). Breaking this further into 10ms bins, it was determined that 220ms reflected a further improvement to accuracy (210-220 ms: 56% accuracy, 16 trials; 220-230 ms: 66% accuracy, 32 trials). This cutoff (220 ms) removed .4% of trials from the faster tail of the distribution (114 trials). For the slower end of the reaction time distribution, data was cut once a dip in accuracy was observed, as this represents an increase in non-task related behaviours (Christie et al., 2015). The same binning procedure was used, and a noticeable dip[3] in accuracy was observed at 800ms (750-800ms: 96% accuracy, 48 trials; 800-850ms: 89% accuracy). Splitting 800-850 into 10ms bins revealed that no further specificity was required. This cutoff (800ms) eliminated .1% of trials from the slower end of the distribution (34 trials).

After these data trimming procedures, participants who did not contribute 70% ‘useable’ trials were excluded from analysis and replaced with another participant[4]. Participants were run with this exclusion principal until the desired sample of 40 participants was reached. Eight participants required replacement based on this criterion (ranging from 36.3 to 69.2 percent usable trials). The remaining 40 participants contributed an average of 430.5 trials each (403.9 when excluding error trials).

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[3] The numerical value that determines what a ‘dip’ is was not set a priori and was determined using visual inspection of the reaction time bins.

[4] This value deviates from the 75% useable trials indicated in the OSF preregistration. Seven of the 40 participants fall between the 70% to 75% range (70, 70, 71, 72, 73, 73, 74), but replacement was not possible due to Covid-19 restrictions.

Statistical Tests

Results from 40 participants (15 male, 4 left-handed, mean age = 20.4 years) were included in statistical analysis. Once the short SOA has expired without a target, performance on targets presented at the long SOA is confounded by the possibility that temporal reorienting will obviate the cueing manipulation. Therefore, our primary analyses will focus on response times to targets presented at the short SOA, as is typical in the literature using the temporal cuing paradigm.

Linear mixed-effect models were used to evaluate the presence of our effects of interest for reaction time (RT). Reaction times were inverted (1/RT) to normalize the distribution. Comparisons between an unrestricted model, which includes the main effect and all lower order effects, and a restricted model, which includes the same lower order effects, is used to see if the evidence accumulated supports the effect or the null. These comparisons are obtained via likelihood ratios, with Akaike's information criterion (AIC) corrections to account for the discrepancy of complexity between models (Akaike, 1974). Ratios are presented in log-base-2, so that positive values can be interpreted as evidence for the effect, and negative values are evidence for the null. The absolute value of the ratio is indicative of the confidence in the model. A relevant and comprehensive explanation of this statistical method can be found in the statistical tools section of Lawrence and Klein (2013). As a general guideline, a ratio of 8 can be considered 'pretty strong' evidence, while 32 is considered 'strong', although this is meant to be used as a continuous metric (Royall, 1977).

Outcomes and Interpretation

Table 2

Mean Reaction Times (and ER) for the short SOA

	Valid	**Invalid**
Intense	386 (6.8%)	396 (6.3%)
Isointense	407 (7.4%)	413 (7.7%)

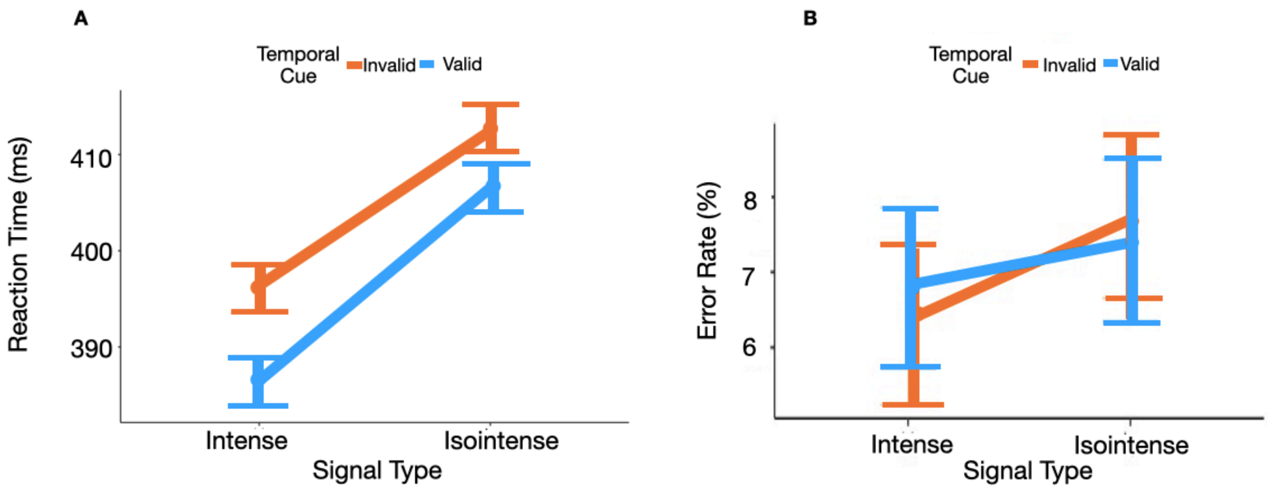

Figure 6: Reaction Time (A) and Error Rate (B) data for the short SOA in experiment one. Signal intensity conditions are separated on the X axis, while the temporal cue validity is split between the orange (invalid) and blue (valid) lines.

Table 3

The short SOA Likelihood Ratios for the inverse of reaction time (1/RT) and error rate (Error) for experiment one. Values are bits of evidence, as calculated via Log-Base-2 AIC Corrected Likelihood Ratios.

Condition	**1/RT**	**Error**
Cue Validity	34.93	-2.88
Signal Intensity	224.70	0.88
Validity * Intensity	0.56	-2.39

As mentioned, this analysis is only on the short SOA data (which is presented in Table 3 and Figure 6). As hypothesized, there was strong evidence for an effect of cue validity on reaction time in this experiment. Participants were faster when presented with valid temporal information in comparison to invalid temporal information (see Figure 7). This strongly indicates the presence of temporal cueing effects. There was also very strong evidence of an effect of signal intensity, in which intense signals produced faster participant responses in comparison to isointense signals (see Figure 7). As previously observed (McCormick, Redden, Lawrence, and Klein, 2018), there is no interaction between validity and intensity.

For error rate, a generalized linear mixed-effect model was run with a binomial distribution. There was no evidence for any main effects or interactions, contrary to what was predicted based on past research (Lawrence & Klein, 2013), but conforming to what has been observed for past intense signal research[5] (see Table 1).

Additional Analysis

Table 4

Mean Reaction Times (and ER) for the long SOA for experiment one

	Valid	Invalid
Intense	403 (4.7%)	402 (5.6%)
Isointense	416 (5.8%)	414 (6.2%)

[5] An additional analysis was run on error rates before the aforementioned exclusions (e.g. reaction time cut-offs, double-presses, switch responses, and responses which did not reach the indicated threshold). This post-hoc analysis did not generate evidence of an effect of signal, cue validity, or an interaction between those two factors, and as such the outcomes were the same as the planned error analysis.

Table 5

The long SOA Likelihood Ratios for the inverse of reaction time (1/RT) and error rate (Error) for experiment one. Values are bits of evidence, as calculated via Log-Base-2 AIC Corrected Likelihood Ratios.

Condition	1/RT	Error
Cue Validity	-2.08	-1.17
Signal Intensity	64.32	2.69
Validity * Intensity	-2.89	-2.68

Likelihood ratios were also calculated for the ‘less analytic’ long SOA. They are considered less analytic because of a participant’s ability to re-orient their attention to the appropriate SOA following an invalid short cue. The likelihood ratio for cue validity suggests there is no evidence of a valid temporal cue benefit. There is evidence of an effect of signal intensity, in which intense signals produce faster responses than isointense signals. There is no evidence of an effect of the various conditions on error rate.

Discussion

The objective of this experiment was to observe temporal cueing effects in both the combined (intense) and purely endogenous (isointense) signalling conditions in a discrimination task so that we could jointly compare performance across speed and accuracy. Prior research found temporal cueing effects in a detection task, but this did not allow for a comparison of accuracy (McCormick et al., 2018). The manipulation of interest in this experiment was the use of a more intuitive cue to offset cognitive effort, and afford assessment of any cuing effects in a discrimination task. As indicated in the previous section, we were successful in generating temporal cueing effects in both the combined condition and the purely endogenous condition. This is further evidence that temporal cueing is mediated by mental effort (Correa et al., 2004; de la Rosa, Sanabria, Capizzi, & Correa, 2012; McCormick et al., 2018), as a previous attempt with an identical methodological structure, but a less intuitive cue, was unsuccessful (McCormick, Redden, Lawrence, & Klein, 2017). Now that it has been shown that temporal cueing effects are possible with both forms of temporal attention in a discrimination task, a comparison of the relationship between speed and accuracy is possible to see exactly how these mechanisms may be differently impacting performance.

However, this experiment joins the long lineage of temporal attention research with no reliable effect upon error rate based on temporal cue validity (see Table 1). Even with our use of appropriate statistical modeling of the binomial error distribution, we find no difference in accuracy between valid and invalid temporal cues. Improved speed with no accuracy differences implies temporal attention improves perception at validly cued trials in comparison to invalidly cued trials. This is also congruent with other research that has studied temporal attention using other methodological tools (Denison, Yuval-Greenberg, & Carrasco, 2019; Denison, Heeger, & Carrasco, 2017). However, when comparing to Lawrence and Klein (2013) who distinguish between the endogenous and exogenous forms in their design, we see a divergence in results. Intense signals should generate a speed-accuracy trade-off in this paradigm, whereas pure improvements to speed and accuracy are expected for the purely endogenous condition. As our task was different than Lawrence and Klein's, where ours involved temporal cues while theirs used fixed temporal intervals, this suggests limits to the generalizability of their findings. When assessing the speed and accuracy results across the diverse spectrum of SOAs they tested, however, it appears that our analytic SOA of 400ms falls within a time-course that may be less sensitive to differences between the two forms (see figure 7, red line).

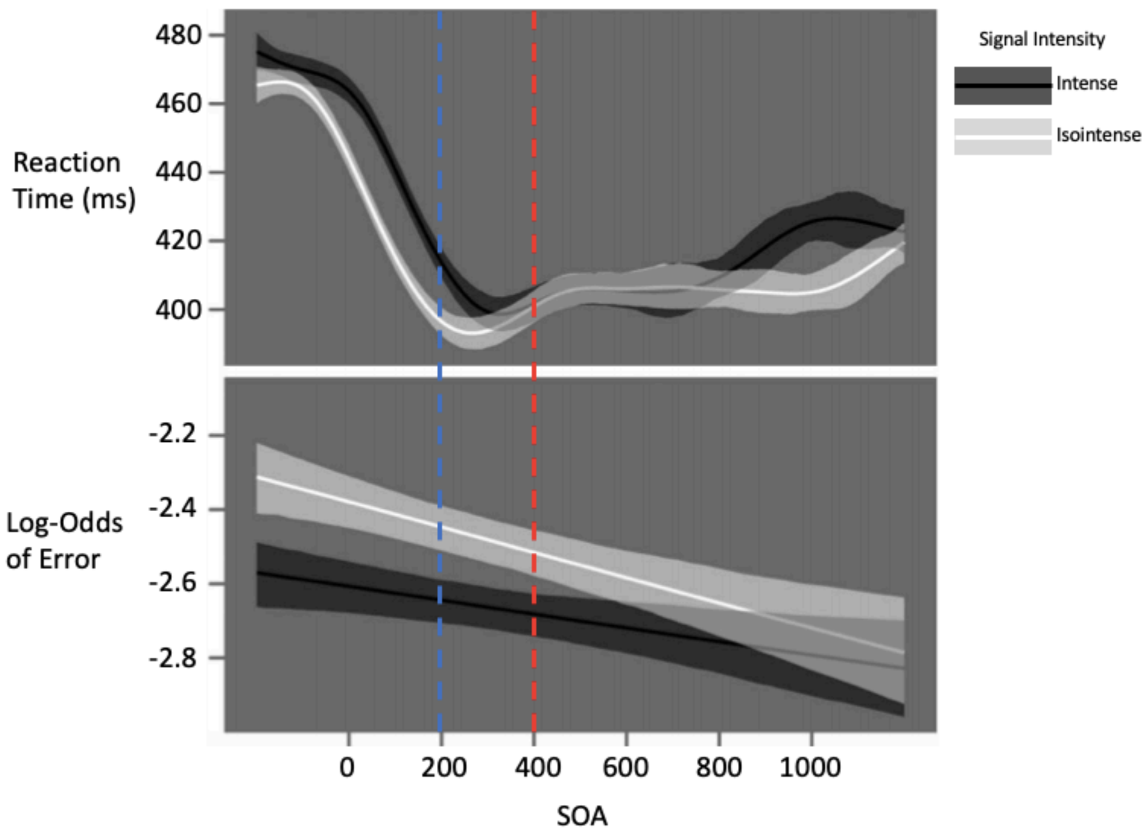

Figure 7: A modified figure from Lawrence and Klein, 2013. The top half shows RT comparisons between intensity conditions, while the bottom shows error differences. The red line represents where E1's short SOA would fall on this figure. The blue line represents the modified short SOA used in E2.

Whereas our task was different than theirs and could therefore generate differences in the time-course of performance, it is worth considering that using a shorter SOA could better lend to performance comparisons between these two intensity conditions. With this consideration in mind, we conducted a second experiment with shorter SOAs.

EXPERIMENT TWO

This experiment aims to observe the anticipated error rate differences in a temporal cueing task by replicating Experiment One but using 200 and 1400ms SOAs instead of 400 and 1600ms. This will shift us earlier along Lawrence and Klein's time-course as illustrated in Figure 7 (blue line). In a past temporal cueing study, Griffin et al (2001) were able to obtain a cueing effect at 200ms when using a detection task, but not when using a discrimination task. However, their cues (two circle sizes for short and long intervals) were likely perceived as less intuitive than the line cues used in our Experiment 1. Where these more intuitive cues generated temporal cueing effects where they were previously absent, we predict that we will continue to observe effects in both signalling conditions using the shorter SOA of 200 ms. If so, we anticipate that the intense signalling condition will generate improved response speed while decreasing accuracy for the valid temporal cue condition, while the isointense signalling condition will improve speed, and perhaps accuracy as well.

Methods

Design

Experiment Two follows the same procedure as Experiment One, except that it changes the SOAs from 400ms and 1600ms for short and long to 200 and 1400ms. All other procedures, stimuli, and equipment are identical.

Registration

This experiment was registered on the Open Science Framework (OSF) prior to the observation of any participant data. This involved description of hypotheses, methodology, and analysis plans. All associated project materials can be found on this project's OSF page (https://osf.io/b28fs).

Participants

Forty-four participants were run in this experiment in a computer laboratory. Data collection sessions involved a maximum of 10 participants at a time. Sessions were run until 40 participants met our trial count criterion. Prior research using this methodology has found reliable effects with 40 participants, which was our rationale for setting this criterion. All participants were undergraduate students at Dalhousie University. All participants had normal or corrected-to-normal vision and hearing.

Results

Data Preprocessing

We used the same metrics to eliminate inappropriate responses from the reaction time data as we did in Experiment One. Pre-target responses were removed (1.1%, 220 trials), along with <.1% (7 trials) of inter-trial responses. Trials were eliminated because the participant pressed both triggers (4.6%, 948 trials), and when participants initiated one response and switched to another (2.1%, 423 trials). Participants did not respond during 67 trials, which were removed from analysis.

We used the same reaction time cut-off procedure as in Experiment One. At the faster end of responses, an increase in accuracy and frequency was observed at 250ms (200-250 ms: 59%

accuracy, 78 trials; 250-300ms: 88.4% accuracy, 1140 trials). Breaking this further into 10ms bins, it was determined that 250ms reflected the best cut-off for performance within the five-bin comparison (250-260ms: 81% accuracy, 76 trials; 260-270ms: 88% accuracy, 131 trials). This removed .5% of trials (98 trials). For the slower end of the reaction time distribution, data was cut once a dip in accuracy was observed, as this represents an increase in non-task related behaviours. The same binning procedure was used, and a dip was observed at 950ms (900-950ms: 100% accuracy, 15 trials; 950-1000ms: 78% accuracy, 9 trials). This eliminated <.1% of trials (9 trials).

After these data trimming procedures, participants who did not contribute 70% 'useable' trials were excluded from analysis and replaced with another participant[6]. This was done until the desired sample of 40 participants was reached. This value was decided beforehand and is in the OSF preregistration. Four participants required replacement based on this criterion (ranging from 24% to 66% percent usable trials). The remaining 40 participants contributed an average of 441 trials each (417.9 when excluding error trials).

Outcomes and Interpretation

Results from 40 participants (5 male, 3 left-handed, mean age = 19.5 years) were included in statistical analysis. Our primary analyses will focus on response times to targets presented at the short SOA. Linear mixed-effect models were used for the transformed RTs (1/RT) for Experiment Two in the same capacity as Experiment One. AIC likelihood ratios were compared, and the ratios are presented in log-base-2.

[6] This value deviates from the 75% useable trials indicated in the OSF preregistration. Three participants fall between the 70% to 75% range (70, 72, 72), but replacement was not possible due to Covid-19 restrictions.

Table 6

Mean Reaction Times (and ER) for the short SOA for experiment two

	Valid	**Invalid**
Intense	399 (6.0%)	408 (6.6%)
Isointense	422 (6.3%)	425 (6.4%)

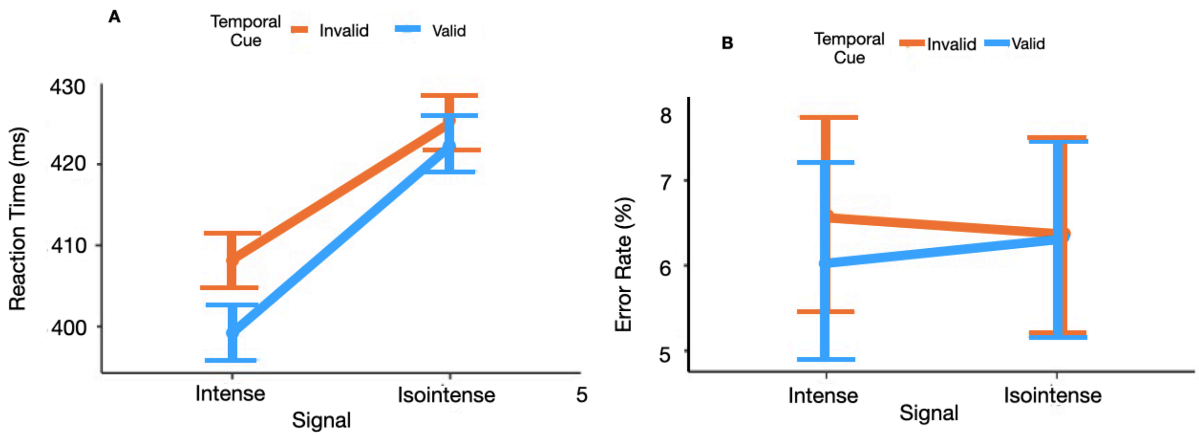

Figure 8: mean RT (left) and ER (right) for the short SOA in experiment two. Signal intensity is indicated on the x axis, while the temporal cue validity is split between the orange (invalid) and blue (valid) lines.

Table 7

The short SOA Likelihood Ratios for the inverse of reaction time (1/RT) and error rate (Error) for experiment two. Values are bits of evidence, as calculated via Log-Base-2 AIC Corrected Likelihood Ratios.

Condition	**1/RT**	**Error**
Cue Validity	10.58	-2.49
Signal Intensity	293.62	-2.77
Validity * Intensity	0.06	-2.63

There is pretty strong evidence of a benefit of temporal cueing in this task, with valid temporal cues generating faster responses than invalid temporal cues (figure 8). Visual inspection of this data seems to indicate that this cueing effect is driven by responses in the intense signalling condition. This is worth consideration and reflects trends observed in past experiments (Capizzi, Sanabria, & Correa, 2012, McCormick et al., 2018), however, there is no evidence of an interaction between signal intensity and temporal cue validity. There is strong evidence of signal intensity impacting reaction time performance, with intense signals generating faster responses than isointense signals.

As was the case in Experiment One, there was no evidence of any effect of our conditions on error rate when comparing generalized linear mixed-effect models with binomial distributions, counter to our prior predictions[7].

Additional Analysis

Table 8

Mean Reaction Times (and ER) for the Long SOA in experiment two

	Valid	Invalid
Intense	408 (4.4%)	409 (3.8%)
Isointense	417 (4.5%)	417 (4.6%)

[7] An additional analysis was run on error rate in which reaction time cut-offs were not implemented, and error rate included double-presses and switch responses. It did not generate evidence of an effect of signal, cue validity, or an interaction between those two factors, so the outcomes were the same as the planned error analysis.

Table 9

Long SOA Likelihood Ratios for the inverse of Reaction Time (1/RT) and Error Rate (Error) for experiment two. Values are bits of evidence, as calculated via Log-Base-2 AIC Corrected Likelihood Ratios.

Condition	1/RT	Error
Cue Validity	-2.71	-2.66
Signal Intensity	25.08	-2.41
Validity * Intensity	-2.80	-1.83

We compared our conditions at the long SOA. As with Experiment One, there was evidence of an effect of signal intensity on reaction time, in which intense signals produced faster reaction times than isointense signals, but no other effects.

Discussion

The aim of this experiment was to compare and contrast how two forms of temporal attention would differently impact reaction time and error rate using two novel SOAs. Due to Experiment One's lack of the expected differences in error rate, we thought presenting the target in a shorter temporal proximity to the signal may generate the expected result. This prediction was based on the data presented in Lawrence and Klein (2013). However, there were still no significant error effects with the shorter intervals. This limits our ability to make comparisons to Lawrence and Klein, and leads us to speculate on the generalizability of their performance categorizations for the two forms of temporal attention.

Although an absent effect of error restricts our ability to compare results between the combined and pure endogenous temporal attention conditions as anticipated, this experiment was successful in generating a temporal cueing effect at the short SOA of 200ms, a novel effect when requiring a discrimination response for this Kingstonian paradigm. This again reinforces the influence of task demand on temporal attention, as using an intuitive cue off-set enough cognitive demand to generate an effect under conditions wherein it was not found previously (Griffin, Miniussi, & Nobre, 2001). It additionally highlights the speed with which temporal attention can be oriented. It is also worth briefly mentioning that there was more evidence of an effect of signal intensity in this experiment in comparison to Experiment One, due to the shortened period between the signal and the presentation of the target. This is the influence of exogenous alerting mechanisms, as they typically peak around this time-course and slowly taper off in the period following (McCormick et al., 2019; Posner, Klein, Summers, and Buggie, 1973).

GENERAL DISCUSSION

The comprehensive goal of this study was to compare purely endogenous temporal attention generated by temporal expectancies, and the exogenous temporal attention generated by intensity. Specifically, we aimed to expand upon the previous work done in this area of research to see how performance may differ between these two conditions when measuring both speed and accuracy. When focusing on speed as a dependent variable, manipulating the cue form alleviated enough cognitive load to allow for temporal cueing effects to be observed for both forms of temporal attention. This was the first time this effect has been found for a purely endogenous condition in a discrimination task, and the second time for any purely endogenous temporal cueing study (next to McCormick et al., 2018). When shifting the analytic SOA to

200ms in an attempt to observe effects at a different position on the speed-accuracy distribution, in reference to Lawrence and Klein (2013; see figure 7), there was evidence that participants were still able successfully orient their temporal attention, once again showing how decreasing the demand of the task frees up temporal resources (Correa et al., 2004; de la Rosa, Sanabria, Capizzi, & Correa, 2012; McCormick et al., 2018). This conclusion seems to run counter to Zanto, Liu, Pan, and Gazzaley (2020), who claim that working memory load does not interfere with temporal cueing performance. Zanto et al., however, found that improved temporal cueing performance was associated with poorer performance on the concurrent task, indicating participants were trading off resources, an indication of cognitive interference.

As we have seen from this set of experiments, the presence of a temporal cueing effect does not guarantee that we will observe the expected contrasts in speed-accuracy performance for intensity (McCormick et al., 2017; McCormick et al., 2018) based on the findings of Lawrence and Klein (2013). Even if one were to speculate that this performance represents motor preparation via alerting instead of the anticipated improvements to both motor preparation and perception, we should still expect to see decreases in accuracy when RT decreases (Posner, Klein, Summers, & Buggie, 1973). Past studies have found that temporal cueing improves both motor preparation (Coull & Nobre, 1998; Griffin, Miniussi, & Nobre, 2002; Correa, Lupianez, Tudela, 2005) and perception (Correa, Lupianez, Tudela, 2005; Davranche, Nazarian,Vidal, & Coull, 2011; Denison, Heeger, & Carrasco, 2017; Denison, Carrasco & Heeger, 2021), depending on their utility to accurately completing a task. With consideration to the point of ‘task-utility’, perhaps Lawrence and Klein’s finding doesn't generalize to the Kingstone task design of cueing the likely temporal interval. For their experiment, participants in the contingent condition (that which is most comparable to our design) were presented with a consistent SOA across the entirety of the block. This meant that in their 400ms block, anytime the signal was presented to participants, the target was always presented 400ms afterwards. This is contrasted by the typical Kingstonian design used in this experiment, where participants are flexibly orienting their temporal attention between two possible SOAs, with a degree on uncertainty of the validity of a cue. There is evidence that when multiple forms of temporal cueing are elicited during a task, they can produce either additive or interactive effects (Nobre & van Ede, 2018). One possible explanation for the divergence of results between our study and Lawrence and Klein's is that the 'hazard rate' form of temporal attention is impacting invalidly cued trial performance in a Kingstone task. Although participants are cued to the long SOA, because there is still a 20% probability of a target appearing at the short SOA, there is an allocation of some temporal resources to this time-point. This is supported by the effect of catch trials (Correa et al., 2004) and interval frequency (Zahn & Rosenthal, 1966) on temporal performance. This emphasizes the importance of methodological control of different factors in task design, along with promoting departure from two alternative forced choice tasks and implementing a more diverse set of tools to study how these two forms of temporal attention are impacting performance.

For the purpose of better understanding the distinctions between the exogenous and endogenous forms of temporal attention, an alternative that may be well suited for studying accuracy and perceptual differences in temporal cueing is using probability and fidelity as performance metrics (Zhang and Luck, 2008). Probability is whether or not the participant had encoded that stimulus, and fidelity is the resolution of that encoding. Probability could be impacted by temporal cue validity, as if a participant is temporally focused at another interval they may miss the target stimuli, but also that fidelity may be impacted by the two different forms of temporal attention, as accuracy differs in past studies (Lawrence & Klein, 2013). Having the target stimuli appear briefly would also likely increase a participant's reliance on temporal cues as well, as there is more cost to performance by not paying sufficient attention to their onset. Additionally, EEG could also be sensitive to contrasts between purely endogenous and combined temporal attention. Contingent Negative Variation (CNV) has been found in relation to temporal attention (Walter et al., 1964) and has two separate components that differently impact performance: an early component, sometimes called the orienting wave, or O wave, which is associated with perceptual preparation, and an expectancy wave, or E wave, which is associated with motor preparation (Correa, Lupianez, Madrid, & Tudela, 2006). We anticipate that the time-courses and amplitudes could potentially be different for these two forms of temporal attention, as the combined form involves exogenous alerting and faster reaction times. Measurement of CNV markers would also confirm the above speculation regarding allocation of varying degrees of temporal preparation based on interval probability. Using a diverse set of tools to compare these two forms of temporal attention will help generate a more comprehensive understanding on how these mechanisms differently operate, and how they impact our processing of the environment.

Open Practices Statement:

All participant data and experiment code, along with the analysis plan registered before any participant data was viewed, can be found at the following link: https://osf.io/dexsm.

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