Title: Temporal processing of emotional stimuli: The capture and release of attention by angry faces

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Abstract

Neuroimaging data suggest that emotional information, especially threatening faces, automatically capture attention and receive rapid processing. Whilst this is consistent with the majority of behavioural data, behavioural studies of the attentional blink (AB) additionally reveal aversive emotional first target (T1) stimuli are associated with prolonged attentional engagement or ‘dwell’ time. One explanation for this difference is that few AB studies have utilised manipulations of facial emotion as the T1. To address this, schematic faces varying in expression (neutral, angry, happy) served as the T1 in the current research. Results revealed that the blink associated with an angry T1 face was, primarily, of greater magnitude than that associated with either a neutral or happy T1 face, but also that initial recovery from this processing bias was faster following angry, compared with happy, T1 faces. The current data therefore provide important information regarding the time-course of attentional capture by angry faces: angry faces are associated with both the rapid capture and rapid release of attention.

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Introduction

An emotional facial expression provides important non-verbal cues as to the imminent behavioural intentions of a second party and hence, important cues to behaviour. For instance, an angry face may communicate direct and immediate harm whereas a fearful face may communicate possible danger or indirect hazards in the environment (Bannerman, Milders, DeGelder & Sahraie, 2009). From a survival perspective both may require rapid and efficient behavioural responding, so it is no surprise that a plethora of behavioural and neuroimaging data demonstrate that facial displays of anger (direct threat) and fear (indirect threat) bias competition for processing resources (see Compton, 2003 and Vuilleumier & Hung, 2009, for reviews). This is consistent with the idea that specific neural circuitry exists for the prioritised and rapid processing of threat-related information (LeDoux, 2000; Phillips, Drevets, Rauch & Lane, 2003) - especially facial stimuli that convey threat. Certainly, when considering threatening facial expression processing, specialised neural networks involving regions of sub-cortical, visual, temporal and frontal brain regions have been proposed based on a substantial volume of neurophysiological, neuropsychological and brain-imaging literature (see Fox et al. 2000; Adolphs, 2002 & Hennenlotter & Schroeder, 2006, for reviews).

In accordance with the general thesis of threat prioritisation, evidence from behavioural investigations utilising rapid serial visual presentation (RSVP) and the attentional blink (AB) paradigm have revealed threatening/aversive stimuli capture and/or hold attention to a greater extent than neutral or positive stimuli (e.g. Anderson & Phelps, 2001; Most, Chun, Widders & Zald, 2005; Maratos, Mogg & Bradley, 2008; Schwabe & Wolf, 2009). In the AB paradigm two targets are presented in an RSVP stream of distractor stimuli. If these targets are presented in quick succession (e.g. within 200-400ms or 2–3 RSVP items), accurate report of the second target (T2) is impaired (see Shapiro, Arnell & Raymond, 1997 or Dux & Marois, 2009 for reviews). The general consensus is that this performance decrement, or AB, reflects attentional demands related to the processing of the first target (T1). However, when the T2 is an angry or fearful face, as opposed to a happy or neutral face, the magnitude of the AB is reduced (Fox, Russo and Georgiou, 2005; Milders, Sahraie, Logan & Donnellon 2006; Maratos et al. 2008). Conversely, when the T1 or distractor stimuli are negative in content (for example an aversive scene or word), the AB has been found to be increased in terms of both magnitude (Most et al. 2005; Srivastava & Srinvasan, 2010) and temporal duration (Mathewson, Arnell & Mansfield, 2008; Peers & Lawrence, 2009) than when the T1 stimulus is positive or neutral in content. That is, when the T1 stimulus is negatively valenced, research reveals that individuals demonstrate a blink of increased magnitude at lag 2 and/or that the effect is prolonged and evident at later lags as well (i.e. of increased temporal duration). In other words, individuals 'dwell' on the threatening stimulus (T2) when T1 is negative.

One question that has yet to be fully addressed is the impact of a threatening T1 *facial* stimulus on processes of temporal attention and the AB, as to date, most studies have utilised either aversive words (Mathewson et al. 2008) or aversive pictorial scenes (Most et al. 2005). Moreover, of the few studies that have utilised manipulations of facial stimuli as the T1, the focus has been on positive compared with negative (e.g. sad) emotions. For example, Srivastava & Srinvasan (2010) found that while both happy and sad T1 faces are associated with an AB for T2 word stimuli, the AB associated with sad T1 faces was of greater magnitude than that associated with happy T1 faces. They argue that this finding reflects the nature of the stimuli and that happy faces are associated with distributed attention whilst sad faces (and negatively valenced stimuli per se) are associated with the narrowing and focusing of attention. Of further importance, Srivastava & Srinvasan found these differences were greatest when the T2 word appeared either 200ms (lag 0) or 300ms (lag 1) after the emotional T1 facial stimulus. This result accords with data emerging from magneto- and electro- encecephalography studies demonstrating brain activity pertaining to negative and/or threatening emotional faces is typically maximal within the first two to three hundred milliseconds of stimulus presentation (e.g. Maratos, Mogg, Bradley, Rippon & Senior, 2009; Hung et al. 2010; Luo, Feng, He, Wang & Luo, 2010). For instance, in periods of high attentional load, such as RSVP, Luo et al. (2010) suggest that *automatic* processing for all negative-valence facial stimuli occurs within 150ms of stimulus processing, followed by *discrimination* and *processing* of threatening facial expressions from other expressions within 250-300ms. Thus it may be the case that the temporal profile of threatening (i.e. aversive) facial stimuli is considerably different to that of aversive word, pictorial and/or sad facial stimuli. Indeed, as speed is particularly important when coping with threat-related information, dwelling on such stimuli may not be an efficient survival strategy; an AB of increased temporal duration following a T1 threatening face may not be conducive to rapid and efficient behavioural responding. To expand, as adaptive behaviour requires rapid switching between relevant external (and internal) stimuli and processes of shift, engagement and disengagement (see Posner & Peterson, 1990 for a review), dwelling on a threat-related stimulus could slow behavioural responses that may be important for survival. That is, dwelling on a threat-related stimulus could delay processes of attention that are required to initiate defensive action in response to this threat. Consistent with this, delayed disengagement or ‘threat dwelling’ is associated with longer reaction times in both visual search and visual probe paradigms (e.g. Georgiou et al. 2005; Hahn, Carlson, Singer & Gronlund, 2006).

In the present study an AB task was utilised in which the valence of the T1 and T2 facial stimuli were manipulated to be angry (i.e. aversive), neutral or happy. Based upon findings from previous RSVP and neuroimaging paradigms, performance was investigated at two lags from within the blink period (i.e. lag 2: 257ms, lag 3: 386ms) and two lags outside of this period (i.e. lag 6: 771ms; lag 7: 900ms). Of specific interest was performance (i.e. detection and identification of the T1 and T2 stimuli) within the blink period dependent upon the valence of the T1 stimuli. If angry faces capture and hold attention in a similar fashion to other negative stimuli such as sad facial expressions, aversive words and/or scenes, then when an angry face serves as the T1 stimulus, performance should be considerably worse at both lags 2 and 3 than when either a neutral or positive face serves as the T1. However, in accordance with neuroimaging literature, if these stimuli are processed more rapidly than non-threatening facial expressions (i.e. within 300ms of stimulus onset), one might expect either a reduced blink effect at both these lags or a greater reduction in the blink effect by lag 3 compared with lag 2 for the angry compared with the neutral or happy T1 face stimuli; that is, a more rapid recovery from the blink effect following a T1 ‘threat’ stimulus compared with a T1 ‘positive’ or ‘neutral’ stimulus.

Method

Participants

Thirty-eight participants (mean age = 28.02, SD = 8.45; 17 male) gave informed consent to participate in the experiment, which received local ethical committee approval. The selection criteria were (i) normal or corrected-to-normal vision and (ii) acceptable levels of single-target detection accuracy, in the control (and main) RSVP tasks (see Procedure for details). The latter criterion was adopted because if participants could not detect a single target reliably in a RSVP stream, their results from critical trials with two targets would be difficult to interpret. One participant was excluded due to below-criterion performance on single-target trials in the main RSVP task. This was defined as performance below two SD of the sample mean. Thus, data from 37 individuals (mean age = 27.9, SD = 8.55; 17 male) were analysed. Participants who completed the experiment received £6 payment.

Stimuli

Four schematic faces were used as target stimuli: a threat face, a positive face and two neutral faces. Schematic rather than real faces were utilised based on data suggesting that they are less prone to potential confounds associated with low-level perceptual features and familiarity (Öhman, Lundqvist & Esteves, 2001; Juth, Lundqvist, Karlsson & Öhman, 2005).

There were also 30 different distractor stimuli, which comprised the key features of each face stimulus in random positions and orientations. All stimuli subtended a visual angle of 5.7^0 x 7.5^0 and were displayed on a black background at a viewing distance of 50cm. Stimulus presentation was controlled by Millisecond software (www.millisecond.com), with each stimulus presented for 128.5ms using a 70-Hz refresh rate.

Procedure

The experiment consisted of two tasks: a short single-target control RSVP task (to ensure all participants could reliably detect a single-target stimulus within an RSVP stream) and the main RSVP task. All trials contained a RSVP stream of 20 stimuli.

In the *control* task (60 trials), a single-target face stimulus, which was the threat face, the positive face or one of the two neutral faces, was presented within a stream of 19 distractor stimuli on every trial. The target face was always preceded by at least four and followed by at least five distractor stimuli and appeared in one of the remaining 11 positions within the stream with equal frequency. Participants were required to press one of three response keys to indicate the expression of the target face (either neutral, positive or threatening with equal measure).

The *main* RSVP task consisted of one block of eight practice trials and three blocks of 90 test trials. Test trials consisted of 70 (26 %) single-target trials and 200 (74%) double-target trials. At the beginning of each trial a small circle was presented for 214ms at the central fixation point. On double-target trials, after the central fixation stimulus, the stimulus events were as follows: an initial sequence of distractor stimuli (ranging from 4 to 8 consecutive stimuli on each trial), the first target (T1), another sequence of distractor stimuli (between 1 and 8 stimuli), the second target (T2), and then the remaining distractor stimuli (between 2 and 13 stimuli) (see **Figure** 1). After each RSVP stream, participants were required to make two consecutive responses to indicate (i) whether one or two faces had been viewed and, if the latter, the emotional expression of the first face viewed (by pressing buttons labelled 1, A, H or N with their left hand) and (ii) the emotional expression of the *last* face viewed (by pressing buttons labelled A, H or N with their right hand). Therefore if participants viewed only one face, they would press the left '1' button followed by the right 'A', 'H' or 'N' button. Thus, participants were asked to *detect* whether 1 or 2 face stimuli had been presented and *identify* the emotional content of the faces viewed - with the right-hand always used to indicate the emotional expression of the *last* face viewed.

Figure 1 about here

The double-target trials of primary interest were those in which the emotional valence of the T1 target had been manipulated and the T2 was a neutral face (either neutral1 or neutral2). This resulted in three main trial types: Threat T1-Neutral T2 (T1 threat trials), Positive T1-Neutral T2 (T1 positive trials) and Neutral T1-Neutral T2 (neutral trials). On each trial, T1 and T2 were always different; i.e. if T1 was neutral2, T2 was neutral1 or vice-versa. For each of these three main trial types, the interval between T1 and T2 contained one, two, five or six intervening distractors, corresponding to a stimulus onset asynchrony (SOA) between T1 and T2 of 257ms (lag 2), 385.5ms (lag 3), 771ms (lag 6) and 899.5ms (lag 7). For each of these lag conditions, there were ten trials for every T1-T2 trial-type. Therefore, in total, there were 40 trials for each of the three main trial types.

To ensure that not all T2 stimuli were neutral, two further double-target trial types were included: 1) 40 neutral T1-threat T2 (T2 threat) trials and 2) 40 neutral T1-positive T2 (T2 positive) trials. Additionally, eight emotional T1-T2 trials (i.e. positive-threat, threat-positive) were included so that not all emotional stimuli were paired with a neutral stimulus. The criteria for these ‘dummy’ trials was i) two per block and ii) that one of the pair always served as trial 1. For each of these trial types, the number of trials at each lag position was again balanced. Thus the final design incorporated a practice block of ten trials and three experimental blocks of 92 trials each after including the two dummy trials in each block.

The single-target trials were similar to the double-target trials; with the exception that only one target was presented at random T1 or T2 positions within the stream. Within each experimental block single and double-target trials were randomly interleaved. The inclusion of single-target trials not only served as a control to monitor target detection performance, but also ensured participants could not employ contingency mapping. For example, if a participant viewed a threat face, they could not necessarily conclude it would be followed (or preceded) by a neutral (or happy) face.

Results

Single-target data

In the control task, the mean percentage of trials in which both the number and type of target were correctly identified was 81% (84%, 77% and 81% for angry, happy and neutral identification respectively). In the main experimental task, the mean percentage of single-target trials in which both the number and type of target were correctly identified was 83% (84%, 78% and 86% respectively). For both data sets, an analysis of variance (ANOVA) of percent correct responses with face type (threat, positive, neutral) and serial position (early, mid, late) as independent variables revealed no effects ($p > 0.20$ in all cases); that is, comparable performance on threat, positive & neutral trials irrespective of target position was observed.

Main RSVP Task – T1 Manipulation

The trials of primary interest were the double-target trials in which the emotional valence of the T1 stimulus had been manipulated. **Figure 2** (main) shows the mean percentage of these trials with correct responses (i.e. trials where both targets were correctly identified) illustrated as a function of trial type (T1 threat, T1 positive, T1 neutral) and lag (four levels). An ANOVA of percent correct responses, with trial type and lag as independent variables, revealed a significant main effect of lag [$F(3, 108) = 129.13$, $p < .001$, $\eta_p^2 = .78$] and a significant interaction between lag & trial type [$F(6, 216) = 6.64$, $p <.05$, $\eta_p^2 = .08$].

*** Figure 2 about here ***

To clarify the latter, a one-way Bonferroni-corrected ANOVA of percent correct responses, with trial type (T1 threat, T1 positive, neutral) as the independent variable, was undertaken separately for each lag position. Results showed a significant difference in performance accuracy between the trial types at lag 2 [$F(2, 72) = 5.35$, $p < .01$, $\eta_p^2 = .13$] and lag 3 [$F(2, 72) = 9.86$, $p < .001$, $\eta_p^2 = .22$]. To establish the cause of these differences, pair-wise Bonferroni corrected comparisons for threat, positive and neutral trial types were undertaken. These simple effects analyses revealed that at lag 2, performance accuracy was significantly worse on T1 threat trials in comparison with T1 neutral trials ($p < .01$) and T1 positive trials ($p < .05$). At lag 3 performance accuracy was significantly worse on T1 threat trials in comparison with T1 neutral trials ($p < .01$) and T1 positive trials compared with T1 neutral trials ($p < .001$). However, there were no differences between performance on T1 threat trials compared with T1 positive trials.

To investigate recovery rates between the two lags as a function of T1 trial type (i.e. disengagement from the T1 stimulus), performance at lag 2 was subtracted from performance at lag 3 for each T1 trial type and the resultant 'recovery bias' score entered into a one-way repeated ANOVA analysis. This revealed a main effect of stimulus type [$F(2, 72) = 4.123$, $p < .05$, $\eta_p^2 = .10$], which Bonferroni-corrected comparisons revealed to be a consequence of significantly faster recovery by lag 3 on T1 threat trials compared with T1 positive trials (p= < .05).

Main RSVP Task – T2 Manipulation

On double-target trials in which the emotional valence of the T2 stimulus had been manipulated (**Figure 2 inset**), ANOVA and corresponding Bonferroni and simple effects analyses revealed that: i) performance accuracy on T2 threat trials and T2 positive trials was significantly better than performance accuracy on T2 neutral trials at lag's 2, 3 & 6 (lag 2: $p < .001$ & 0.01; lag 3: $p < .001$ & 0.01; lag 6: $p < 0.01$ & 0.05, for threat and positive trials respectively); and ii) performance accuracy on T2 threat trials was significantly better than performance accuracy on T2 positive trials at lag 2 ($p < .01$). This result is consistent with that of Maratos et al. (2008).

Discussion

In the present study the manipulation of primary interest was that of the T1 facial stimulus. The purpose of this manipulation was to assess the impact of emotional, and especially threatening, facial stimuli on processes of temporal attention as measured by the attentional blink (AB) effect. To this end, results revealed that at lag 2 the AB associated with T1 threat trials was significantly greater than that associated with either T1 neutral or T1 positive trials. However, by lag 3 performance associated with T1 threat trials was equivalent to performance associated with T1 positive trials, with an analysis of bias scores further revealing faster recovery from the AB by lag 3 on T1 threat trials compared with T1 positive trials. Therefore, in part, these findings are consistent with both previous RSVP and neuroimaging data (e.g. Most et al. 2005; Srivastava & Srinvasan, 2010; Hung et al. 2010; Luo, et al. 2010); i.e., the attentional prioritisation of threat stimuli as demonstrated by the greater magnitude of the blink effect at lag 2 on T1 threat trials. In addition, they indicate that angry face stimuli are associated with both the rapid capture *and* rapid release of attention, as demonstrated by the more rapid recovery from the blink effect observed on T1 threat trials in comparison with T1 positive trials.

Previous AB research has revealed that when the T1 stimulus is negative or aversive in content the magnitude and duration of the AB is greater than when the T1 stimulus is neutral or positive (Mathewson et al. 2008; Schwabe & Wolf, 2009; Srivastava & Srinvasan, 2010). In accordance with this, the current data demonstrate that an aversive T1 facial stimulus (i.e. an angry face) is also associated with an AB of increased magnitude at lag 2. However, unlike aversive and negative word or picture stimuli, the angry T1 facial stimulus was not associated with an AB of increased temporal duration. Namely, a greater degree of recovery from the blink effect was evident by lag 3 following an angry T1 facial stimulus compared with a happy T1 facial stimulus. Whilst direct comparisons with previous aversive word and pictorial stimuli research should be made tentatively, given i) the differing methodologies employed and ii) the unavoidable confound of differing task demands as a consequence of the different stimulus categories utilised (e.g. words vs. faces) (see Martens, Dun, Wyble & Potter, 2010), importantly, the present results suggest that participants did not 'dwell' on the angry face stimulus. This finding accords well with recent face processing data from neuroimaging literature (e.g. Maratos et al. 2009; Hung et al. 2010; Luo et al. 2010).

Indeed, during periods of increased attentional load, Luo et al. (2010) suggest that threatening facial stimuli, unlike their non-threatening counterparts, are processed within 300ms of stimulus presentation. The present data offer some support for this proposal given that on T1 threat trials the T2 stimulus presented at lag 2 fell within this time frame (i.e. 257ms), but that presented at lag 3 fell outside of this period (i.e. 386ms). This suggests that at lag 2 the angry T1 face received a narrowed attentional focus, but by lag 3 competition between stimuli for processing resources had been re-established; that is, by lag 3 processes of disengagement and shift were evident following the T1 threat stimulus. However, there were no differences between recovery rates for T1 neutral trials compared with T1 threat trials by lag 3 compared with lag 2. One possible explanation for this result is that as neutral stimuli are neither associated with heightened attentional capture nor rapid processing, recovery from the blink period may start earlier for this stimulus type, but inevitably last longer. Thus in the current paradigm the necessary time period to discern differences in recovery rates for these different stimuli was not of suitable precision (i.e. contained too few lags). Therefore, one important line of future research would be to investigate recovery associated with emotional and neutral T1 facial stimuli using a more extensive time period. For example, the use of an AB paradigm additionally encompassing lag 1 or lags within the 400-700ms time range, as Srivastava & Srinvasan (2010) suggest that differences in AB performance can be discerned as late as lag 5 (corresponding to a time frame of 643ms using the present design).

A further valid extension of this work would be an investigation of the neural correlates associated with the AB for emotive compared with non-emotive facial stimuli. Whilst Luo et al. (2010) have tried to assess this; their focus was on event-related components associated with the AB. Additionally, as lag 2 performance was near ceiling (i.e. 93 ± 5%) in the paradigm adopted by Luo et al., reliable investigation of blinked stimuli was not possible. In the current research, lag 2 performance averaged 20% for the T1 manipulation and 40% for the T2 manipulation. As such, the current paradigm would allow for a more valid investigation of brain activity underlying the AB – i.e., ‘blinked’ stimuli.

The difference in performance related to the paradigm adopted by Luo et al. (2010) and the paradigm adopted here could reflect the use of schematic rather than real faces in the present investigation. Indeed, a potential limitation of schematic faces is that there are few exemplars per expression category (e.g. only one angry face was used here). In addition, Horstmann, Borgstedt and Heumann (2006) have suggested that both emotional and perceptual variables could contribute to their effects.

Consistent with such research, Coelho, Cloete & Wallis (2009) provide evidence to suggest that it may be the very low-level aspects of schematic faces - the number and strength of visual features aligned radially within a stimulus, for example - that confer the threat superiority effect. While the idea that low-level perceptual features may be responsible for such an effect is not inconsistent with recent neuroimaging literature (e.g. Vuilleumier, Armony, Driver and Dolan; 2003; Maratos et al. 2009), to further investigate this hypothesis, in future AB studies of emotion processing a 'non-face' T1 condition should be incorporated. In this condition the T1 stimulus should be composed of *exactly* the same features as the T1 emotional (or threat) face stimulus and demonstrate the same symmetry, but be configured in such a way that a (threatening) face percept is not identifiable.

A final aspect for consideration is whether the more rapid recovery from the blink effect following the angry T1 stimulus compared with the happy T1 stimulus was associated with the valence or arousal aspect of the angry T1 stimulus (or both). Thus in future research the use of schematic sad faces as well as fearful faces alongside angry faces is advisable. Whilst Srivastava & Srinvasan (2010) have demonstrated that sad faces are associated with a blink of greater magnitude and duration than happy faces, the AB methodology employed was sufficiently different to warrant further investigation of this factor. Additionally, whilst Milders et al. (2006; see also Fox et al. 2005) have observed an attentional blink of reduced magnitude when the T2 stimulus is of indirect threat (i.e. a fearful face), to date, no studies have investigated the profile of the attentional blink following a fearful compared with angry T1 face. This is despite research by Williams & Mattingley (2005; 2006) demonstrating that angry faces are detected significantly faster than fearful faces in visual search. While Williams & Mattingley (2006) suggest that the perceptual processing of these two threat types reflects differing evolutionary pressures i.e. prioritisation of the rapid processing of anger compared with fear, assessing the blink profile following a fearful T1 face as well as an angry T1 face would be useful in evaluating this premise.

In sum, the present study provides preliminary support for the idea that angry faces are associated with both rapid attentional capture and rapid attentional release (i.e. disengagement). This finding accords with the idea that processing threatening information efficiently poses several survival advantages. However, future research is warranted to: i) more extensively investigate the time course of this phenomenon, ii) verify that it holds for use with real faces and iii) investigate whether the phenomenon is specific to angry as opposed to sad, or even fearful, T1 faces.

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Figure Captions

Figure 1. An example of a double-target trial in which T1 was a threat face and T2 was a neutral face (N1).

Figure 2. **Main:** Mean percentage of correct answers (with standard error bars) on double-target trials in which the T1 was manipulated; i.e. the T1 was a threat, positive, or neutral face and the T2 a (different) neutral face. **Inset:** Mean percentage of correct answers (with standard error bars) on double-target trials in which the T2 was manipulated; i.e. the T1 was a neutral face and the T2 was a threat, positive, or (different) neutral face.

Figure 1

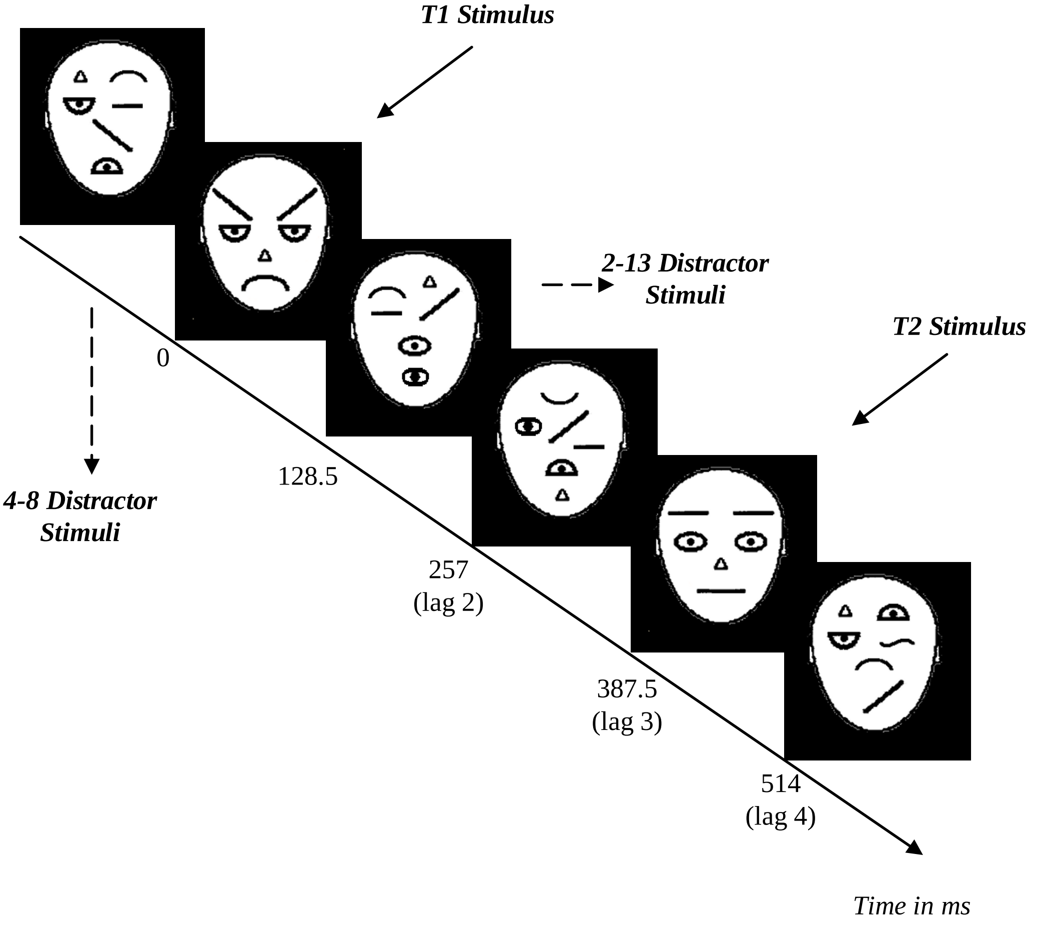
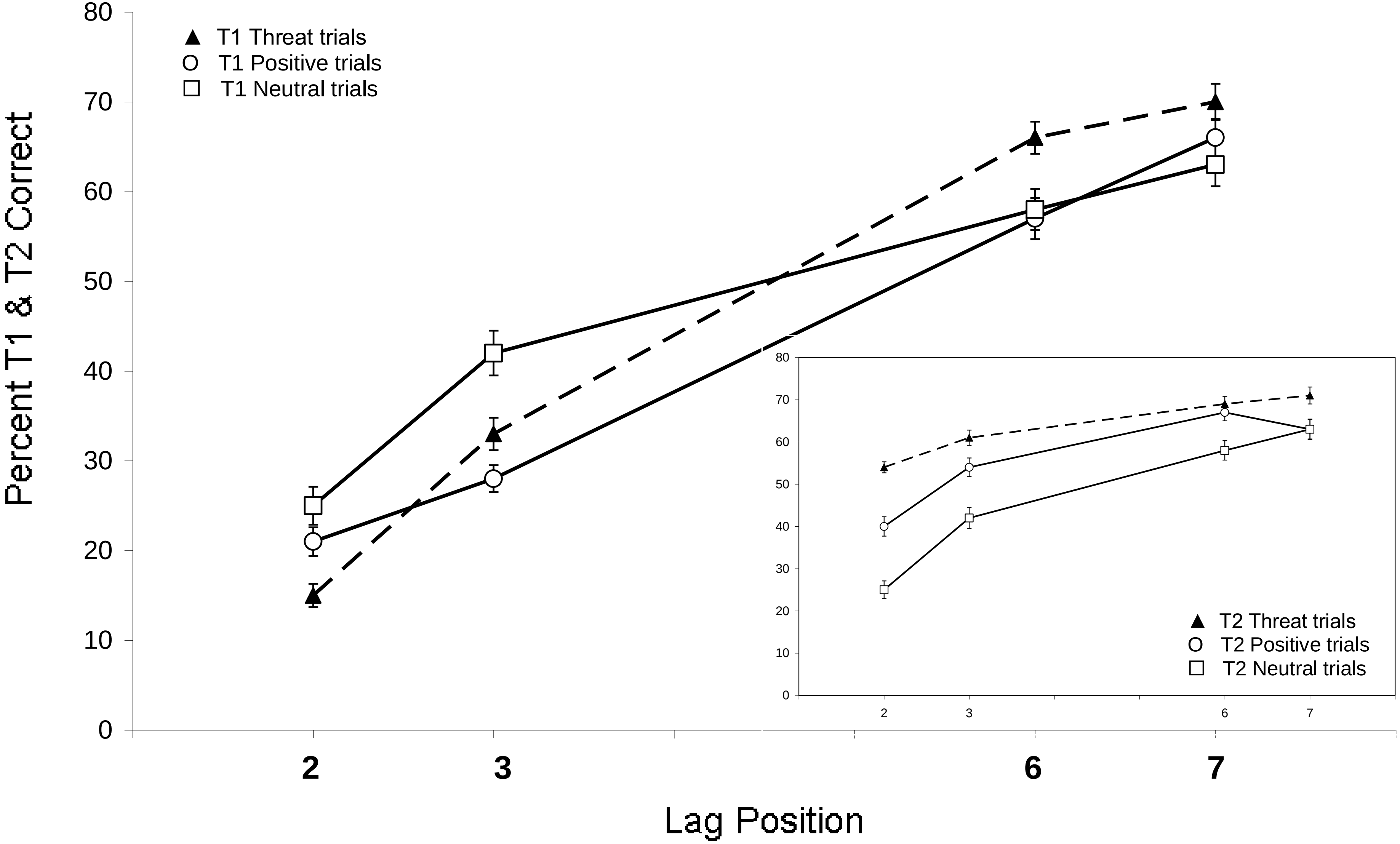

T1 Stimulus
2-13 Distractor Stimuli
T2 Stimulus
0
4-8 Distractor Stimuli
128.5
257
(lag 2)
387.5
(lag 3)
514
(lag 4)
Time in ms

Figure 2



T1 Threat trials
T1 Positive trials
T1 Neutral trials
Percent T1 & T2 Correct
0
10
20
30
40
50
60
70
80
2
3
6
7
Lag Position
T2 Threat trials
T2 Positive trials
T2 Neutral trials