Cognitive, Affective, & Behavioral Neuroscience (2018) 18:1000–1014
https://doi.org/10.3758/s13415-018-0618-0

Attentional responses on an auditory oddball predict false memory susceptibility

John E. Kiat[1] · Dianna Long[1] · Robert F. Belli[1]

Published online: 20 June 2018

Abstract
Attention and memory are highly integrated processes. Building on prior behavioral investigations, this study assesses the link between individual differences in low-level neural attentional responding and false memory susceptibility on the misinformation effect, a paradigm in which false event memories are induced via misleading post-event information. Twenty-four subjects completed the misinformation effect paradigm after which high-density (256-channel) EEG data was collected as they engaged in an auditory oddball task. Temporal-spatial decomposition was used to extract two attention-related components from the oddball data, the P3b and Classic Slow Wave. The P3b was utilized as an index of individual differences in salient target attentional responding while the slow wave was adopted as an index of variability in task-level sustained attention. Analyses of these components show a significant negative relationship between slow-wave responses to oddball non-targets and perceptual false memory endorsements, suggestive of a link between individual differences in levels of sustained attention and false memory susceptibility. These findings provide the first demonstrated link between individual differences in basic attentional responses and false memory. These results support prior behavioral work linking attention and false memory and highlight the integration between attentional processes and real-world episodic memory.

Keywords Episodic memory · Attention · False memory · P300 · Electroencephalography · Oddball

Introduction

Attention and memory are interdependent, tightly integrated, processes (Aly & Turk-Browne, 2017; Chun & Turk-Browne, 2007). Attentional processing during encoding influences what information is processed and stored (Uncapher & Rugg, 2005) while synchronously, prior memory traces influence and guide the allocation of attentional resources (Stokes, Atherton, Patai, & Nobre, 2012). Similar processes present themselves during retrieval where efficient memory performance relies on attentional control in maintaining task focus (Unsworth & Robison, 2016) and inhibiting irrelevant recollective traces (Anderson & Green, 2001), while memory traces moderate task focus (Rummel, Smeekens, & Kane, 2017), serve as attention cues (Hutchinson & Turk-Browne, 2012), and impact available attentional resources (Whitmer & Gotlib, 2013). The retrieval process itself can be conceptualized as a form of selective attention towards internal representations (Badre, Poldrack, Pare-Blagoev, Insler, & Wagner, 2005; Chun & Turk-Browne, 2007).

Attention and false memory

This rich interconnected framework necessitates a key role for attention in real-world memory, particularly with regard to promoting accurate retrieval and preventing false memory formation. There are a wide range of tasks used to study false memory, these include the Deese-Roediger-McDermott paradigm, a task in which false report of unpresented words are induced via the study of other related words (Roediger & McDermott, 1995), as well as reality-monitoring paradigms, which strive to induce: (a) false perceptual memories for items presented in different modalities (Hoffman, 1997; Johansson, Stenberg, Lindgren, & Rosén, 2002), or (b) false self-action memories for imagined or observed actions (Goff & Roediger, 1998; Lindner, Echterhoff, Davidson, & Brand, 2010).

Attention has been shown to play an important role in many of these paradigms (DRM: Dewhurst, Barry, Swannell, Holmes, & Bathurst, 2007; MacRae, Schloerscheidt, Bodenhausen, & Milne, 2002; Perez-Mata, Read, & Diges,

✉ John E. Kiat
johnkiat@huskers.unl.edu

[1] Department of Psychology, University of Nebraska-Lincoln, 34 Burnett Hall, Lincoln, NE 68588-0308, USA

2002; Skinner & Fernandes, 2009. Source Monitoring: Bayen & Kuhlmann, 2011; Dywan, Segalowitz, & Webster, 1998; Fernandes & Moscovitch, 2000). However, with regard to false memories for complex real-world event memories, although several studies have shown divided attention (Palmer, Brewer, McKinnon, & Weber, 2010; Sauer & Hope, 2016) and increased attentional load (Murphy & Greene, 2016) to have a negative impact on event memory in general, the link between basic attentional processes and the formation of this class of false memories remains an underexplored area of research.

To induce false event memories experimentally, researchers typically utilize the well-established misinformation paradigm. In this design, individuals witness an event, receive misleading post-event information, and are later tested on their memories for the original event (Loftus, 2003). During testing, participants frequently misreport misinformation-based details as being part of the original event. Intriguingly, these false reports are often accompanied by perceptual recollections comparable with (Belli, Lindsay, Gales, & McCarthy, 1994) although weaker than true memories (Schooler, Gerhard, & Loftus, 1986).

The primary studies linking attention to false memory susceptibility have been conducted by Tousignant, Hall, and Loftus (1986), Zaragoza and Lane (1998), Lane (2006), Rivardo et al. (2011), and Kiat and Belli (2017). Tousignant et al. (1986) showed that experimental manipulations and individual differences which increased the amount of time allocated towards reading misleading post-event misinformation – a proxy measure for attention – was associated with reduced levels of misinformation susceptibility. Tousignant et al. (1986) proposed that this elevated attention was linked with increased levels of discrepancy detection, a hypothesis supported by several other investigations in the area (Blank & Launay, 2014; Higham, Blank, & Luna, 2017; Polak, Dukała, Szpitalak, & Polczyk, 2016). Building on Tousignant et al. (1986)'s work, Zaragoza and Lane (1998) conducted a study that linked attention and misinformation susceptibility more directly by demonstrating that dividing attention during the misinformation exposure stage led to higher levels of susceptibility to false memory formation. Extending this line of research, Lane (2006) found that dividing attention during the event encoding stage also led to increased susceptibility to false memory formation as well as reduced memory for event details. Lane (2006)'s findings were supported by Rivardo et al. (2011), who showed individual differences in the level of attention during event encoding to be positively related to accurate event memory and reduced levels of false event memory susceptibility. Finally, Kiat and Belli (2017) focused their investigation on the memory retrieval phase of the misinformation paradigm and found evidence indicating that differences in the level of attentional response to recognition cues during this stage could be used to differentiate true and false perceptual event memory responses.

To the best of our knowledge, despite evidence showing differences in attention exerting a significant influence on false memory susceptibility, no study has sought to directly link individual differences in basic attentional neural responses to the considerable between-subject variability in false memory formation. Furthermore, given the multifaceted nature of attention (see Petersen & Posner, 2012, for a review), the specific aspects of attentional processing most strongly associated with susceptibility to false memory formation have also yet to be isolated. The goal of the current study is to shed light on these empirical issues.

Attention-related neural responses

As this investigation is the first to assess individual differences in attentional processing and false memory susceptibility using neural measures, we chose the well-established two-stimulus Oddball task (Kok, 2001; see Polich, 2007 for a review; Squires, Squires, & Hillyard, 1975) as a measure of neural individual differences in attentional responding. In the classic Oddball paradigm, two or more different stimuli are presented in a random series, with one of them (the target) occurring relatively infrequently. The participant is then tasked with noting the occurrence of every target stimulus by pressing a button or mentally counting the number of non-frequent targets, suppressing responses to frequent and, in the three-stimulus variant of the task, non-frequent, non-target stimuli.

Decades of event-related potential (ERP) research using the two-stimulus Oddball paradigm have shown it to elicit several distinct neural responses. Given our focus on attention, we concentrate on two attentional- related components, the P3b (Sutton, Braren, Zubin, & John, 1965), a positive centroparietal component peaking between 250 and 500 ms post-stimulus presentation (see Kok, 2001; Polich, 2007 for a review), and the classic positive slow-wave response, a posterior component extending approximately 400–700 ms post-stimulus (Barry, Steiner, & De Blasio, 2016; Brown, van der Wee, van Noorden, Giltay, & Nieuwenhuis, 2015; García-Larrea & Cézanne-Bert, 1998; Johnson & Donchin, 1985; Loveless, Simpson, & Naatanen, 1987; Ruchkin, Sutton, Kietzman, & Silver, 1980; Spencer, Dien, & Donchin, 2001; Squires et al., 1975; Steiner, Barry, & Gonsalvez, 2013; Struber & Polich, 2002). While both components have been repeatedly shown to be more positive in response to target trials compared to non-target trials, multiple investigations have shown them to be modulated by distinct factors, indicating that the two components reflect distinct cognitive processes (Brown et al., 2015; Ruchkin & Sutton, 1983; Ruchkin et al., 1980; Rushby, Barry, & Doherty, 2005; Spencer et al., 2001; Steiner et al., 2013).

The widely studied P3b response is associated with operations involved in assessing the degree to which incoming targets match internal representations in memory and allocating processing resources for context related updating (Donchin, 1981; Kok, 2001; Polich, 2007). The P3b has been specifically linked with inhibitory mechanisms associated with minimizing extraneous stimulus processing in facilitation of task-relevant memory operations (Polich, 2007). As such, the P3b response has been widely used as a measure of differences in the level of attention oriented towards salient task-relevant targets and information (Berlad & Pratt, 1995; Chen et al., 2011; Gray, Ambady, Lowenthal, & Deldin, 2004). Multiple studies have found relatively stable levels of inter-individual variability in the P3b response (Conroy & Polich, 2007; Williams et al., 2005). These differences have been mapped onto a range of behavioral differences including working memory capacity (Yurgil & Golob, 2013), base arousal levels (Brocke, Tasche, & Beauducel, 1997) and cognitive ability (Russo, De Pascalis, Varriale, & Barratt, 2008; Stelmack & Sculthorpe, 2008).

The classic 'slow wave' is less well understood than the P3b, likely due to many studies not making a distinction between the two components or utilizing analytic methods that are unable to do so effectively. Nonetheless, prior investigations involving the Oddball slow wave shed some light on the cognitive processes underlying the component. One of the most direct assessments of the slow wave was conducted by Struber and Polich (2002), who found the slow wave to be elevated not only towards Oddball targets relative to nontargets, but also towards one-target stimuli monitoring responses under long (30 s) relative to short (2.5 s) interstimulus-intervals. Based on this observation, which was similar to a prior effect noted by Fitzgerald and Picton (1981), Struber and Polich (2002) proposed the slow wave to be indicative of cognitive operations associated with the maintenance and adjustment of attentional processes related to task monitoring. Likewise, Kok and de Jong (1980) and Ruchkin and Sutton (1983) also associated increases in the Oddball slow-wave amplitude with increased levels of general alertness and sustained task related focus. Slow wave responses in other non-Oddball related target detection paradigms have also been repeatedly associated with task-level sustained attention and resource allocation (Gevins et al., 1996; Ritter & Ruchkin, 1992; Rozenkrants & Polich, 2008; Rushby et al., 2005). This interpretation of the slow-wave response is also in line with repeated findings showing the amplitude of the component to be elevated as a function of increased task difficulty (see Rosler & Heil, 1991, for a review).

Building on this body of work, individual variation in the P3b and classic slow-wave components have significant potential as indexes of individual differences in salient target attentional responses, and task-level sustained attention respectively. Measuring the response to the highly salient targets and repetitive non-targets further extends this framework, allowing the potentially differential relationship between attentional resources allocated towards these distinct classes of stimuli and false memory susceptibility to be assessed.

The present study

The objective of this study is to assess links between low-level individual differences in attentional responding and susceptibility to false memory formation on the misinformation effect paradigm. Individual differences in attentional responding were assessed via ERP recordings from a classic two-stimulus Oddball task, whereas misinformation susceptibility was assessed using materials adapted from Okado and Stark (2005).

The two primary attention-related components of interest in this investigation are the P3b and Classic Slow Wave, proposed as indexes of saliency driven and sustained attentional responding respectively. Given the broad definition of attention utilized in prior investigations of attention and false memory, it is difficult to make firm predictions regarding potential differential links between the P3b and slow-wave components with regard to false memory susceptibility. Nonetheless, prior studies have shown divided attention (Lane, 2006; Zaragoza & Lane, 1998) and lower levels of inherent task-related attention (Tousignant et al., 1986) to be associated with increased levels of misinformation susceptibility. As these factors appear more strongly associated with sustained attention as opposed to saliency responding, we hypothesize prior demonstrated links between attention and false memory susceptibility on the misinformation effect are driven by reduced levels of overall sustained attentional allocation leading to decreased levels of event encoding (Lane, 2006) and discrepancy detection (Tousignant et al., 1986; Zaragoza & Lane, 1998). Thus, we hypothesize that individual differences in amplitude of the slow-wave response will be negatively associated with misinformation susceptibility as this response is the closest to being an index of individual differences in top-down sustained attention. We also hypothesize that the individual differences in P3b response will also be negatively associated with misinformation susceptibility given the link between discrepancy detection and reduced false memory susceptibility (Tousignant et al., 1986).

Methods

Power estimation

The target sample size was estimated using empirical power simulation in SAS 9.3 (Zhao & Li, 2012) with behavioral parameters observed in data from a prior investigation utilizing these materials (Kiat & Belli, 2017) and evoked response potential (ERP) data from an oddball dataset collected using the same equipment utilized in this investigation (Kiat 2018). With these parameters, 1,000 simulated datasets were simulated for ten potential target sample sizes (10–40 in increments of five) for target effect sizes between $r = .25$ and $r = .75$. The results of this analysis indicated that based on these parameters, a sample size of 25 participants was sufficient to provide 80% power to detect effect sizes of $r \geq .50$ between the oddball measures and behavioral responses on the ERP task.

Participants

Twenty-seven undergraduate psychology students (16 female, mean age = 19.68 years, *SD* = 2.29), were recruited from a subject pool at a large public university for this study. Three participants were excluded from the analysis due to excessive noise and artifacts in their ongoing EEG, resulting in a final sample of 24 subjects (13 female, mean age = 19.87 years, *SD* = 2.31). All participants reported right-handed dominance as measured by the Edinburgh Handedness Inventory (Oldfield, 1971). Each participant received research credit for their participation and provided written informed consent. The Institutional Review Board of the university approved all study procedures.

Materials

Oddball task A two-stimulus auditory Oddball was utilized in this study. The target stimulus was a 1,000-Hz tone (Probability: 20%) while the non-target stimulus was a 500-Hz tone (Probability: 80%) with all tones being presented for 350 ms each. All tones were presented from a speaker positioned approximately 1 m above the midline of participants' heads. The amplitude of all tones was 75 dB SPL as measured at participants' ears. A total of 324 tones (36 infrequent, 288 frequent) were presented with the stimulus-onset asynchrony, which between 1,250 and 1,750 ms, with the precise value being randomly generated for each trial. Examples of each tone and a three-trial practice run (one target, two non-targets) were presented to familiarize participants with the task and stimuli prior to the start of the actual task. Participants were instructed to sit still with their eyes open, blinking normally, throughout the task. To rule out motor activity as a confound, participants were instructed to mentally count the number of target tones presented to them during the task (Debener, Makeig, Delorme, & Engel, 2005). At the end of the task, respondents were asked to provide the number of target stimuli that had been presented. To equalize the number of target and non-target trials for subsequent processing, a randomly selected set of 36 frequent tone trials were labeled a priori for later segmentation.

Misinformation task This task had three phases: event study, misinformation exposure, and test. In the study phase, participants viewed four event sequences, each depicted using a series of 50 digital color slides (Okado & Stark, 2005). These separate events depicted (a) a man breaking into a car, (b) a woman's wallet being stolen, (c) a repairman stealing office supplies, and (d) two friends getting into a fight. Presentation order was randomized across participants. Each slide was presented for 3,500 ms with a 500-ms blank screen between slides. Twelve slides from each series contained critical details, half of which served as targets of misinformation and half as control items during a later narrative phase.

The study phase was followed by the misinformation exposure stage in which participants studied four narratives, each purportedly redescribing one of the previously presented events. Each narrative consisted of 50 sentences, one for each event slide, each presented on-screen for 3,500 ms with a 500-ms blank screen between sentences. Six of the event details were described inaccurately (misinformation) with the other six described accurately (consistent control). Two versions of the narrative were created, perfectly counterbalancing the assignment of critical details to the misinformed and consistent control conditions. Participants were randomly assigned to read one of these two variants. In the final test phase, participants were tested on all 24 misinformed details and all 24 control items, six from each event in both cases. Prior to testing, participants were told that they would be tested on specific aspects of the events that had been previously presented in the preceding event and narrative slides. Participants were told that the test was a True/False sentence rating task and that after making each response they would be asked to indicate whether they had made that response based on something they remembered seeing ("Seen"), reading ("Read"), both seeing and reading ("Both Seen and Read) or if they were just guessing ("Guess").

The testing procedure is presented in Fig. 1. Each test item was tested individually using a procedure utilized in our prior work involving these materials (Kiat & Belli, 2017). First, a partial sentence reinstated the context of the target event detail. This sentence was presented on-screen for 4,000 ms after which the critical event detail which completed the sentence was presented. This event detail was either accurate (control) or misinformation based (misled item). After the presentation of each event detail, participants made a True/False judgment followed by a source attribution judgment (seen, read, seen and read, or guess), on the basis of the recalled source on which they were basing their True/False evaluation. All responses were made on a four-key button box. A blank screen was presented for 2,000 ms between each trial. Test items were blocked by event type and presented in random, non-chronological order within blocks. A short sentence reinstated the context of each event at the start of each block.

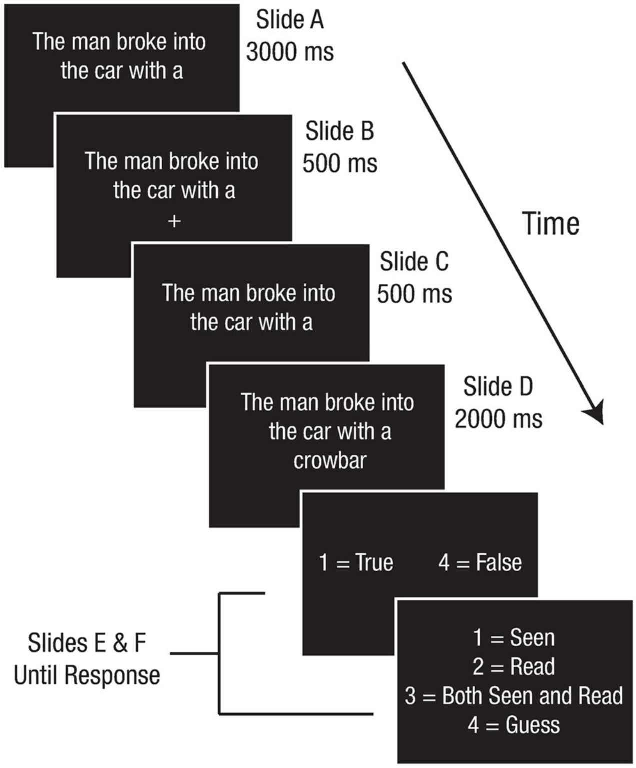

Fig. 1 Misinformation test procedure

Experiment procedure

The study consisted of single test session during which participants completed both the misinformation and Oddball tasks. Participants were told that they would be participating in a psychological study of memory involving the completion of several memory and attention-related tasks. They then provided informed consent for the study after which they were seated individually in sound-attenuated rooms and fitted with the high-density EEG electrode net. All stimuli were presented on a 21-in. computer monitor adjusted to be 1 m from the midline of their faces at a resolution of 1,024 × 768 pixels. Two experimenters monitored the participant and the ongoing real-time EEG waveforms for ocular and movement artifacts.

The testing procedure of the study was as follows. Participants first completed the misinformation event study phase followed by a 20-min retention interval during which participants engaged in a filler task involving studying word lists (none of which were related to the depicted events). After completing the filler task, participants were informed that they would not be tested on the lists. They then completed the misinformation narrative study phase. This stage was followed by a 15-min retention interval in which the impedences of the electrode net were inspected and re-adjusted if necessary. After the impedances had been adjusted, participants completed the Oddball task followed by the misinformation testing phase.

EEG data acquisition

EEG data were recorded using a 256 high-density AgCl electrode Hydrocel Geodesic Sensor Net connected to a high-input impedance NetAmps 300 amplifier running Netstation version 4.4.2. Electrode impedances were kept below 45 kΩ, a level appropriate for the high impedance system used. The EEG data were digitized at 1,000 Hz from the DC to 500 Hz range using a 24-bit analog-to-digital converter. Recordings were collected using a vertex sensor (Cz), later referenced to an average reference.

EEG preprocessing

The continuous EEG data were first digitally filtered using a 0.1-Hz first-order high-pass and 30-Hz lowpass filter. The continuous data were then downsampled to 250 Hz and segmented to the onset of the preselected frequent and all infrequent tones, beginning 200 ms before onset and continuous for 1,200 ms thereafter. Segments were then baseline-corrected using the 200-ms prestimulus average. Ocular artefacts were reduced via decomposing the data into basic topography components using Delorme and Makeig (2004)'s *runica* routine and removing ICA components with correlations greater than .90 with a blink template created via averaging 200 blinks from open-eye resting-state data recorded from 40 subjects from a separate study (each subject contributing five blinks) using an identical system setup.

After the artifact reduction process, bad channels were then identified and interpolated in the segments using the ERP Principal Component Analysis (PCA) Toolkit's preprocessing functions. Bad channels were identified across the entire session via poor overall correlations (r <0.60) between neighboring channels and within each segment either as unusually high differences between an electrode's average voltage and that of their neighbors (> 30 μv) or as extreme voltage differences within the electrode (> 80 μv min to max). A channel was also marked as bad for the entire session if more than 20% of its segments were classified as being bad. All identified bad channels were replaced using whole head spline interpolation. After bad channels were identified and interpolated, trials that had more than 8% of their channels interpolated were removed from the analysis set. The remaining trials were then referenced to an average reference. Average ERPs for each condition were calculated using a mean-average approach. Post rejection, each subject retained an average of 31.5 infrequent (SD = 4.50) and 31.88 frequent (SD = 3.92) trials. These trial numbers have been shown to be more than sufficient for reliable measurement of the P300 component (Cohen & Polich, 1997).

Results

Oddball behavioral performance

Performance on this task was close to ceiling with 18 of the participants indicating having detected all 36 tones. On average, participants reported detecting 35.71 (SD = 0.55, Range = 34–36) of the 36 infrequent tones.

Misinformation behavioral performance

Performance on this task is presented in Tables 1 and 2. Table 1 shows the breakdown of control items as a function of their endorsement (i.e., rated as "True") versus rejection (i.e., rated as "False") status and their subsequent source judgments. Table 2 presents the same breakdown for misinformed items.

Responses given perceptual attributions (i.e., "Seen" and "Seen and Read" responses) are the critical response categories focused on in all subsequent analyses. This focus draws on prior source monitoring-focused investigations of misinformation susceptibility to originally presented visual information (Belli et al., 1994; Higham, 1998; Kiat & Belli, 2017; Mitchell, Johnson, & Mather, 2003). "Seen" and "Seen and Read" source attributions are of primary interest in this study as they represent accurate visual perceptual source attributions for event items and inaccurate visual perceptual source misattributions of misinformation content. The latter class of responses (i.e., perceptual misinformation endorsements) is of particular interest as they, relative to the other response categories, come closest to representing instances of false-event-related memories.

Pairwise t-tests indicated that participants made more control endorsements than misinformation endorsements with perceptual attributions ($t(23) = 8.33$, $p < .0001$, $r^2 = .75$), with no significant difference in number of perceptual based misinformation rejections compared to misinformation endorsements ($t(23) = 1.46$, $p = .157$, $r^2 = .09$). Adopting a signal detection framework in which control endorsements = hits, control rejection = misses, misinformation endorsements = false alarms and misinformation rejections = correct rejections indicated a high level of discrimination sensitivity (d' = 1.043) and an endorsement response bias (β_G = .684) (Macmillan, 2005).

An analysis of the response time data found that participants took longer to respond to misinformation endorsements (M = 1,730.86 ms, SD = 792.37) relative to control endorsements (M = 1,381.86 ms, SD = 619.04, $t(23) = 2.17$, $p = .041$, $r^2 = .17$). There were no response-time differences with regard to misinformation endorsements and misinformation rejections (M = 1701.90, SD = 1325.71, $t(23) = .12$, $p = .905$) or control endorsements and misinformation rejections ($t(26)$ = 1.24, $p = .228$, $r^2 = .06$).

ERP component extraction

Given the known overlap between the P3b and classic slow-wave components (Brown et al., 2015; Rosler & Heil, 1991; Ruchkin et al., 1980; Spencer et al., 2001), temporal-spatial decomposition was utilized to decompose the underlying component structure of the Oddball ERP response. This method has frequently been utilized to separate P3b and slow-wave components (Barry et al., 2016; Brown et al., 2015; McDonald, Gabbay, Rietschel, & Duncan, 2010; Spencer et al., 2001). Components were estimated using temporal-spatial PCA in ERP PCA Toolkit version 2.49 (Dien, 2010a). First, a temporal PCA was performed on the data using all time points from each participant's averaged ERP as variables, considering participants, condition, and recording sites as observations. This step reduced the temporal structure of the ERP data (350 measurement points) to a set of temporal components. Promax rotation was used (Dien, 2010b) and 32 temporal components were extracted based on a 95% variance-accounted-for criterion.

The spatial distribution of these components was then decomposed using spatial PCA. This PCA used all recording sites as variables, considering participants, conditions, and temporal factor scores as observations. This step reduced the 257-channel electrode structure to a set of virtual electrodes on which the original electrodes loaded on. Infomax rotation was used (Dien, 2010b) and five spatial components (78% of total variance) were extracted based on parallel analysis.

Selection of the P3b and slow-wave components was done in a two-step process. First, components that accounted for at least 5% (60 ms) of temporal-spatial variance were identified. Two components met this criterion, a central-posterior component (see Fig. 2A–D) with a peak timespan (component temporal loadings > 0.8) 272–400 ms post-onset (10.87% of total variance) and an extended posterior positivity (see Fig. 2E–H) peaking 416–612 ms post-onset (10.05% of total variance). Based on their time-course and topography in light of prior work (see Polich, 2007 for a review), the first component was classified as the P3b whereas the second was classified as the anticipated slow-wave response. The time-course of the

Table 1 Control items: response proportions with standard deviations in parentheses

Condition	Seen	Seen and read	Perceptual attribution	Read	Guess	Total
Endorsement	.108 (.151)	.524 (.173)	**.632 (.108)**	.123 (.092)	.057 (.060)	**.813 (.094)**
Rejection	.063 (.071)	.040 (.038)	**.102 (.069)**	.030 (.031)	.056 (.063)	**.188 (.094)**

The perceptual attribution proportions in bold text in Tables 1 and 2 represent the sum of Seen + Seen and Read responses

Table 2. Misinformed items: response proportions with standard deviations in parentheses

Condition	Seen	Seen and read	Perceptual attribution	Read	Guess	Total
Endorsement	.267 (.202)	.087 (.086)	**.354 (.163)**	.035 (.059)	.049 (.057)	**.438 (.164)**
Rejection	.061 (.076)	.215 (.153)	**.276 (.147)**	.224 (.139)	.063 (.046)	**.563 (.164)**

The perceptual attribution proportions in bold text in Tables 1 and 2 represent the sum of Seen + Seen and Read responses

both components is congruent with prior work involving the auditory P3b and slow-wave response (Barry et al., 2016; Brown et al., 2015; Debener et al., 2005; Spencer et al., 2001; Struber & Polich, 2002; Wronka, Kaiser, & Coenen, 2012). Intriguingly, the topography and time course of the observed slow-wave component closely matched the attributes of the slow-wave late positive component shown in our prior work (Kiat & Belli, 2017) to differentiate true and false recognition memories.

Source localization of the neural sources of the components was conducted by specifying a pair of hemispheric dipoles (mirrored in position but not orientation) in Fieldtrip

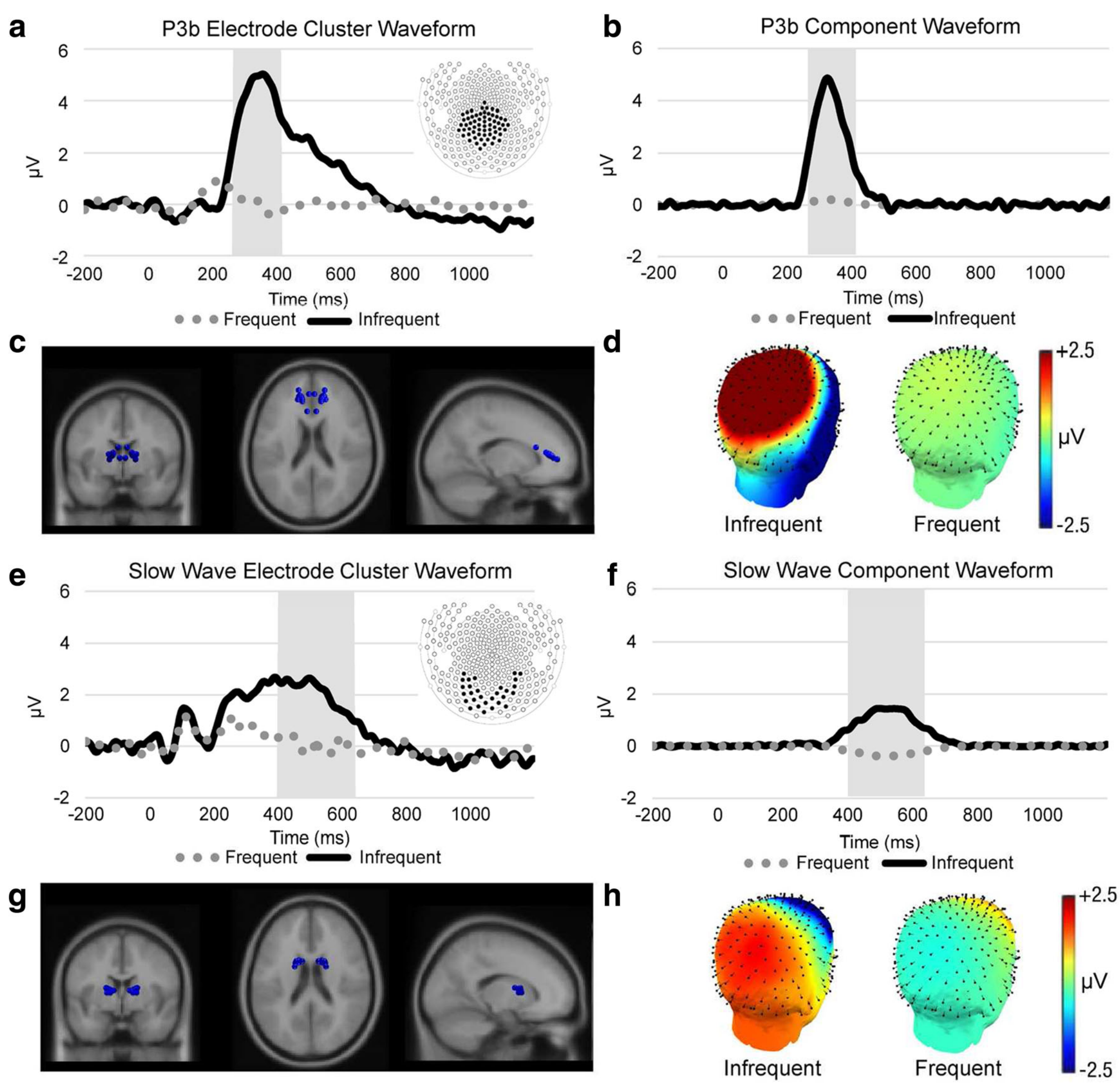

Fig. 2 P3b and slow-wave components. (**A**) Grand average waveforms for electrodes with high loadings (> 0.75: marked in black on the electrode map) on the P3b component with high loading (> 0.75: 272– 400 ms) time points shaded in grey. (**B**) P3b component waveforms on the highlighted electrode map. (**C**) Jack-knifed dipole solution for the P3b component (**D**) P3b component scalp topography by condition. (**E**) Grand average waveforms for electrodes with high loadings (> 0.75: marked in black on the electrode map) on the slow-wave component with high loading (> 0.75: 416–612 ms) time points shaded in grey. (**F**) Slow-wave component on the highlighted electrode map. (**G**) Jack-knifed dipole solution for the slow-wave component. (**H**) Slow-wave component scalp topography by condition

(Oostenveld, Fries, Maris, & Schoffelen, 2011) using a four-shell model in ERP PCA toolkit version 2.49 (Dien, 2010a). A grid scan first produced an estimate of the best starting position after which an iterative algorithm identified the position of maximum fit using maximum-likelihood (Lütkenhöner, 1998). The stability of the solution was then assessed with a jack-knife technique where the spatial PCA solution was recomputed 24 times, each with one of the participants left out.

As indicated in Fig. 2, this procedure identified the anterior cingulate ($RV = 4.50\%$) as being the most likely neural generator of the P3b component. The jack-knife analysis supported this result. Out of the 24 jack-knife solutions, each indicated by a blue marker in Fig. 2C, all localized to the anterior cingulate cortex (ACC). The localization solution of the slow-wave component identified the caudate nucleus ($RV = 1.22\%$) as the most likely generator source. The jack-knife analysis supported this result. Out of the 24 jack-knife solutions, each indicated by a blue marker in Fig. 2G, all localized to the caudate nucleus.

The localization of the P3b component to the ACC is in line with numerous prior EEG (Bachiller et al., 2015; Mulert et al., 2004; Volpe et al., 2007), fMRI (Clark, Fannon, Lai, Benson, & Bauer, 2000; Kiehl, Laurens, Duty, Forster, & Liddle, 2001; Kiehl et al., 2005; Stevens, Calhoun, & Kiehl, 2005), combined fMRI-ERP (Bledowski et al., 2004; Stevens et al., 2005), and simultaneous fMRI-EEG (Crottaz-Herbette & Menon, 2006; Li, Wang, & Hu, 2009; Strobel et al., 2008) investigations of the neural sources of the P3b response.

While to the best of our knowledge no study has sought to directly localize the Oddball slow-wave component separately from the P3b, activation in the caudate has been previously noted in prior Oddball investigations utilizing simultaneous fMRI (Kiehl et al., 2001; Kiehl et al., 2005) and fMRI-EEG (Crottaz-Herbette & Menon, 2006; Strobel et al., 2008; Walz et al., 2013) have also shown increased levels of effective connectivity between the caudate and ACC in response to Oddball target processing. Also, in line with the idea that the slow wave is associated with sustained attention (Gevins et al., 1996; Ritter & Ruchkin, 1992; Rozenkrants & Polich, 2008; Rushby et al., 2005), electrotomographic investigation of neural connectivity on the Oddball task has found evidence indicating damage to the caudate region impairs resistance to irrelevant distractors (Bocquillon et al., 2012).

Oddball EEG analyses

Means and standard deviations for the P3b and slow-wave components by Oddball stimuli condition are presented in Table 3. P3b and slow-wave component voltage scores were both significantly more positive in response to infrequent relative to frequent stimuli ($t(23) = 9.288$, $p < .001$, $r^2 = .790$; $t(23) = 5.549$, $p < .001$, $r^2 = .572$ respectively).

Table 3. P3b and slow-wave voltages by condition: means and standard deviations

Condition	P3b	Slow wave
Infrequent	8.27 μV (4.40)	4.41 μV (4.73)
Frequent	.36 μV (1.02)	-1.16 μV (3.00)

Infrequent responses were significantly correlated across-components ($r(24) = .416$, $p = .043$), whereas the correlation between frequent responses across-components was not significant ($r(24) = -.220$, $p = .301$). The within-components correlation for both frequent and infrequent responses was also not significant for either the P3b ($r(24) = .335$, $p = .108$) or slow-wave component ($r(24) = .253$, $p = .233$), suggesting a reasonable level of independence between the two responses.

ERP component-misinformation performance analytic strategy

The relationship between the P3b and slow-wave Oddball responses and perceptual misinformation endorsement levels (i.e., "True" responses to misinformation focused test statements given either a "Seen" or "Seen and Read" source attribution) were modeled using linear mixed effects models with maximum likelihood estimation and a random intercept for subjects. The P3b and slow-wave responses to targets and non-targets were entered into each model simultaneously. The decision to assess these links simultaneously and separately as opposed to calculating a single difference score was driven by prior work that has shown the overall target and non-target P300 response to be differentially modulated by factors related to attentional processing (Inoue, Inagaki, Gunji, Kokubo, & Kaga, 2007; Jonkman et al., 1997; Rosenfeld, Bhat, Miltenberger, & Johnson, 1992). A Bonferroni correction was applied to the four hypothesized tests of interest (i.e., Target P3b – Perceptual Misinformation Endorsement. Non-Target P3b – Perceptual Misinformation Endorsement. Target Slow Wave – Perceptual Misinformation Endorsement. Non-Target Slow Wave – Perceptual Misinformation Endorsement).

P3b-misinformation links

As shown in Fig. 3, the results showed P3b responses to frequent ($F(1,21) = .16$, $p = .690$) and infrequent ($F(1,21) = .03$, $p = .860$) stimuli to not be significantly related to perceptual misinformation endorsements levels. The difference between these two effects was also not statistically significant ($t(1,21) = .33$, $p = .745$). Neither of the P3b responses was significantly related to accurate perceptual memory report levels ($p = .932$ and $.246$ for infrequent and frequent responses respectively).

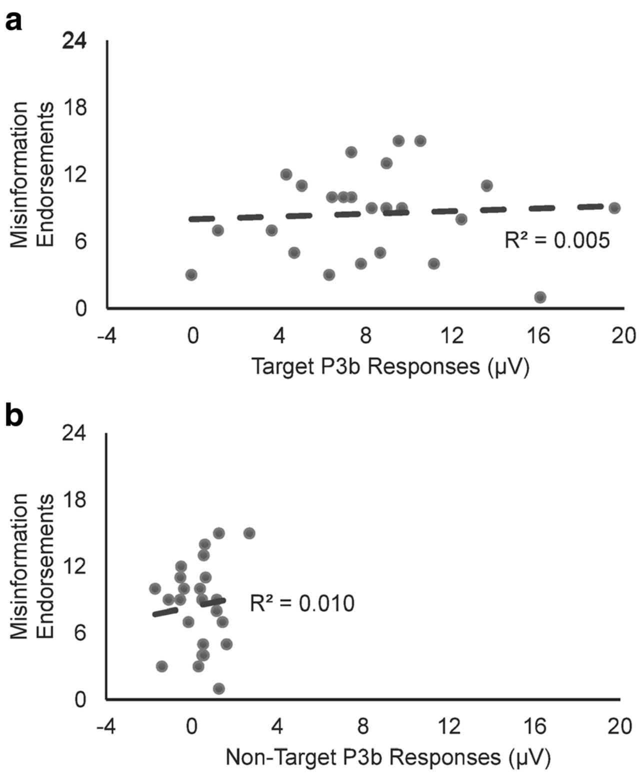

Fig. 3 Plot of perceptual misinformation endorsement scores versus P3b component voltage for (**A**) infrequent and (**B**) frequent Oddball stimuli

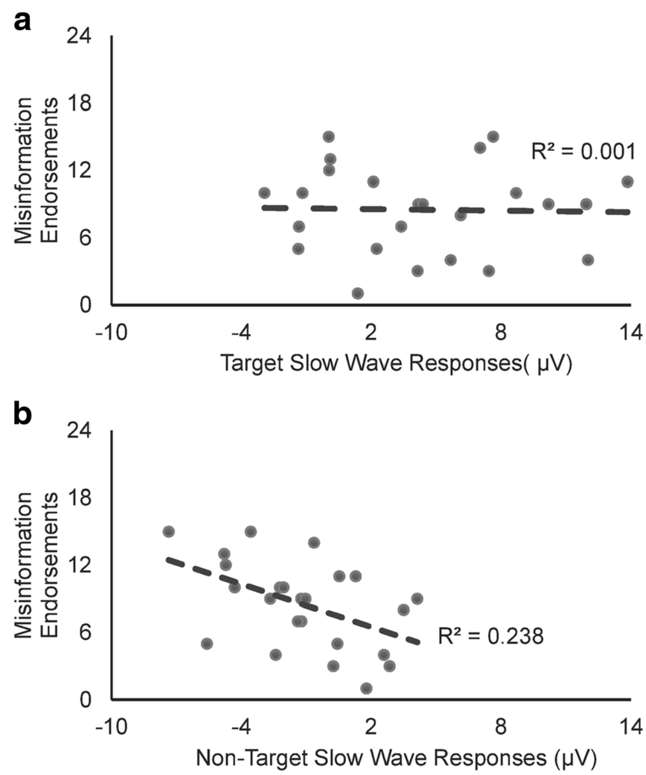

Fig. 4 Plot of perceptual misinformation endorsement scores versus slow-wave component voltage for (**A**) infrequent and (**B**) frequent Oddball stimuli

Slow-wave misinformation links

As shown in Fig. 4, while the slow-wave response to infrequent stimuli was not significantly related to perceptual misinformation endorsement levels (i.e., "True" responses to misinformation based test statements given either a "Seen" or "Seen and Read" source attribution) ($F(1,21) = .32$, p = .579), the slow-wave response to frequent stimuli was strongly related to perceptual misinformation endorsements ($F(1,21) = 7.90$, $p = .010$). The difference between these two effects was statistically significant ($t(1,21) = 2.41$, $p = .025$). These results found more positive slow-wave responses to frequent stimuli to be associated with fewer perceptual misinformation endorsements, indicative of reduced misinformation susceptibility. Neither of the slow-wave responses was significantly related to accurate true perceptual memory report levels ($p = .492$ and .947 for infrequent and frequent responses respectively).

Discussion

The hypotheses of this study are partially supported by the observed results. While P3b amplitudes were not significantly linked with misinformation susceptibility, individual differences in the slow-wave response to non-targets on the two-stimulus Oddball were significantly predictive of false perceptual memory reports on the misinformation effect paradigm, accounting for almost a quarter of the observed between-subject variability. These findings represent the first demonstrated link between individual variation in attentional neural responses and false memory susceptibility. These results also lend support to prior behavioral work linking manipulations of attention (Lane, 2006; Zaragoza & Lane, 1998) and individual differences in attentional responding (Kiat & Belli, 2017; Rivardo et al., 2011) with false memory susceptibility. The slow-wave and P3b findings are discussed separately in the following sections

Slow-wave findings

The slow-wave findings are in line with prior work linking task-level divided attention manipulations (Lane, 2006; Zaragoza & Lane, 1998) and overall levels of task-related attention (Tousignant et al., 1986) with false memory susceptibility (Tousignant et al., 1986). These results are consistent with our hypothesis that task-level divided attention effects shown in prior work capitalize most directly on reducing top-down attentional resources, and that differences in maintaining sustained attention strongly influence false memory susceptibility. In line with this prediction, we found a relationship between false memory susceptibility and reduced levels of slow-wave response toward non-salient non-targets which, lacking bottom-up attentional capture characteristics, arguably represent the most direct index of individual differences in top-down sustained attention. This interpretation draws on prior work which lends support to the view of slow-wave responses reflecting task-level sustained attentional monitoring and resource allocation (Gevins et al., 1996; Kok & de Jong, 1980; Ritter & Ruchkin, 1992; Ruchkin & Sutton, 1983; Rushby et al., 2005; Struber & Polich, 2002).

It was interesting to note that the slow-wave response to targets was not associated with misinformation susceptibility in this study. This finding is not without some precedence as prior work has shown that the links between the global P300 response towards targets and non-targets exhibit differential relationships to attention-related factors (Inoue et al., 2007; Jonkman et al., 1997; Rosenfeld et al., 1992). While these prior investigations did not decompose the P300 into its underlying components, the general finding in these investigations is that the non-target P300 is more sensitive to task engagement or arousal levels relative to the target P300 (Rosenfeld et al., 1992) and is reduced in amplitude in attention-deficit individuals, among whom the target P300 may not be as impaired (Inoue et al., 2007; Jonkman et al., 1997). Collectively these prior findings suggest that the target P3 slow-wave response may be more strongly related to aspects of processing the attention capturing characteristics of presented targets while the nontarget slow-wave response may be more strongly related to sustained attention-related processes. It is also possible, despite best efforts to isolate the P3b and slow-wave components, that the slow-wave response to targets still contains portions of the target P3b response. The apparent lack of any link between the target slow wave and misinformation susceptibility ($R^2 = .001$) does, however, suggest that this account cannot fully explain the observed effect as one would anticipate at least a directional link between these two factors even if the target slow wave was contaminated by other underlying components.

Intriguingly, the topography and time course of the Oddball slow-wave component observed in our study closely matches with the attributes of a slow-wave late positive component shown in our prior work (Kiat & Belli, 2017) to differentiate true and false recognition memory responses to retrieval cues at test. Considering this match in light of conceptualizations of memory retrieval as a form of attention towards internal representations (Badre et al., 2005; Chun & Turk-Browne, 2007), it is interesting to consider the possibility that these two slow-wave components reflect similar underlying processes. Further investigations into this potential link may provide useful insights on the links between attention and memory processing.

It is also interesting to place these results in context with the extant literature on models of attention. One of the most useful frameworks to draw on in this regard is Corbetta and Shulman (2002)'s two-attention network model. Building on Mesulam (1999) and Posner and Petersen (1990)'s frameworks, Corbetta and Shulman (2002)'s model proposes an interplay between two networks in the attentional orienting process: (a) a goal-directed dorsal frontoparietal network associated with preparation and top-down target selection and detection and (b) a stimulus-focused ventral frontoparietal network associated with the orienting of attention towards salient stimuli.

Drawing on Corbetta and Shulman (2002)'s framework, Kim (2014) recently conducted a meta-analysis of studies involving the Oddball paradigm. Kim (2014)'s meta-analysis found evidence for a strong association between ventral network activation and Oddball response effects, indicative of a stimulus-driven "alerting" system. Dorsal network activation was, however, less strongly associated with Oddball responses which Kim (2014) proposed as possibly being due to the activation being subtracted out from the network's involvement in maintaining general levels of externally focused attention to both Oddball and standard stimuli. This interpretation is supported by fMRI work by Mantini, Corbetta, Perrucci, Romani, and Del Gratta (2009), who showed activation in a ventral-network focused ICA component to be transiently moderated by Oddball stimuli while a dorsal-network focused ICA network showed sustained levels of activity throughout the task.

Given that it was non-target responses that were predictive of false memory susceptibility, it may be that the slow-wave response that we observed is more strongly associated with dorsal network related individual differences in sustained attention throughout the task. This interpretation gains support from the localization of the slow-wave component to the caudate, which has been linked with several aspects of executive functioning (Grahn, Parkinson, & Owen, 2009) including sustained attention (Coull, Frackowiak, & Frith, 1998; Lawrence, Ross, Hoffmann, Garavan, & Stein, 2003; Mendez, Adams, & Lewandowski, 1989) and attentional control (Corbetta, Miezin, Dobmeyer, Shulman, & Petersen, 1991; Cortese et al., 2016; Grahn, Parkinson, & Owen, 2008; Montes et al., 2010; Schrimsher, Billingsley, Jackson, & Moore, 2002). Prior work linking damage in the caudate region to impaired dorsal frontoparietal connectivity and impaired resistance to distractors (Bocquillon et al., 2012) also lends support to the hypothesis of the observed effect being linked with sustained dorsal network related attentional processes.

P3b findings

It is interesting to note that, contrary to expectations, individual differences in P3b responding were not significantly associated with misinformation susceptibility. This finding can be interpreted in several ways. Firstly, it is possible that the discrepancy detection related processes that reduce misinformation susceptibility (Tousignant et al., 1986) are not directly related to the context-updating related processes that are believed to drive the P3b response (Donchin & Coles, 1988; Polich, 2007). It is also possible that the stimuli used in this study were overly salient, subsuming subtler contributions of individual differences in this domain. The relatively low levels of variability in the P3b response towards non-targets lends some support to this hypothesis. Nonetheless, these hypotheses are speculative and warrant further research to be properly tested.

It is also intriguing to note that neither the P3b or slow-wave component were predictive of true perceptual event memories. These findings may be partially due to a ceiling effect created by the high levels of performance with regard to true event memories (84% mean accuracy with several subjects having perfect or near-perfect scores) relative to misled memories (56% mean accuracy with no subject exceeding 84%). Speculatively, it may also be that the observed effects are primarily driven by the differences in the level of attention participants allocate during the misinformation study phase. As this stage represents a potentially repetitive second round of study for the participants, it may be that participants with lower attentional resources devoted to the Oddball task were less able to sustain attention to the repetitive and less engaging verbal materials in the misinformation phase, which would likely result in higher levels of misinformation susceptibility (Lane, 2006). True memories, on the other hand, may draw more strongly on the first event study phase which, being the first round of study and visually engaging in nature, may have engaged the attention of all respondents fairly equally. This hypothesis is however speculative and warrants additional study.

Limitations and future directions

One of the main limitations of our study is that foil test items (i.e., items not present in the event and not misled on in the misinformation narrative) were not presented during the testing stage. This decision was motivated by our desire to maximize the number of misinformation items to ensure a sufficiently reliable measurement of individual differences in this regard. Including counterbalanced foil items would have naturally reduced the number of critical misled items. Unfortunately, this exclusion led to an inability to test for the presence of a misinformation effect in the traditional sense. Given the focus of this study is on individual differences in misinformation susceptibility, which is solely measured by misinformation endorsements, this limitation does not have a significant impact on the conclusions of this investigation. Nonetheless, it would be interesting to assess links between attentional responding and foil endorsement susceptibility as a measurement factor in future investigations.

In addition to this future direction, there are several other interesting lines of research that build off the present findings. Firstly, there is the possibility that engagement in a sustained attention monitoring task prior to testing exerts an influence on test performance. For instance, engagement of higher levels of attentional monitoring related processes during the oddball task may have carried over to the misinformation test phase, positively impacting test performance on misled items. This potential for a causal relationship between these pretest attentional tasks and misinformation susceptibility would be an intriguing one to consider in future research. It may also be interesting to investigate the potential for a curvilinear relationship between these two factors by assessing the impact of administering progressively more demanding attention-related tasks prior to testing. Drawing on prior work showing a positive link between divided attention and misinformation susceptibility attention (Lane, 2006; Zaragoza & Lane, 1998), it is possible that engaging in sufficiently demanding tasks prior to testing could deplete attentional resources sufficiently as to result in increased misinformation susceptibility.

For instance, it would be interesting to assess links between behavioral measures of sustained attention and susceptibility to misinformation on the misinformation effect paradigm using tasks like the Sustained Attention to Response Task (SART; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). Linking basic attentional processes to false memory susceptibility also lays the groundwork for further assessment of the processes underlying a wide range of memory phenomena. Future investigations integrating other classic paradigms such as the Go/No-go and dichotic listening could, for instance, shed light on links on the differential roles of attentional control and selective attention with regard to false memory susceptibility. Furthermore, there are a wide range of paradigms used to study false memory such as the Deese-Roediger-McDermott paradigm (Roediger & McDermott, 1995) and other reality and source-monitoring focus designs (Goff & Roediger, 1998; Hoffman, 1997; Johansson et al., 2002; Lindner et al., 2010). Given the growing awareness among false memory researchers on the surprising level of independence between many of these false memory tasks (Calvillo & Parong, 2016; Garoff-Eaton, Slotnick, & Schacter, 2006), a focus on underlying basic processes has the potential to shed light on the differential mechanisms which almost certainly underlie different forms of false memory. Moving the discussion to a shared language involving interactions between shared basic cognitive processes has significant potential to accelerate progress on these fundamental issues in false memory research.

Funding This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Compliance with ethical standards

Conflict of interest None.

References

Aly, M., & Turk-Browne, N. B. (2017). How Hippocampal Memory Shapes, and Is Shaped by, Attention. In D. E. Hannula & M. C. Duff (Eds.), *The hippocampus from cells to systems: Structure, connectivity, and functional contributions to memory and flexible cognition* (pp. 369-403). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-50406-3_12

Anderson, M. C., & Green, C. (2001). Suppressing unwanted memories by executive control. *Nature*, *410*, 366-369. https://doi.org/10.1038/35066572

Bachiller, A., Romero, S., Molina, V., Alonso, J. F., Mananas, M. A., Poza, J., & Hornero, R. (2015). Auditory P3a and P3b neural generators in schizophrenia: An adaptive sLORETA P300 localization approach. *Schizophrenia Research*, *169*(1-3), 318-325. https://doi.org/10.1016/j.schres.2015.09.028

Badre, D., Poldrack, R. A., Pare-Blagoev, E. J., Insler, R. Z., & Wagner, A. D. (2005). Dissociable controlled retrieval and generalized selection mechanisms in ventrolateral prefrontal cortex. *Neuron*, *47*(6), 907-918. https://doi.org/10.1016/j.neuron.2005.07.023

Barry, R. J., Steiner, G. Z., & De Blasio, F. M. (2016). Reinstating the novelty P3. *Scientific Reports, 6*, Advance online publication. https://doi.org/10.1038/srep31200

Bayen, U. J., & Kuhlmann, B. G. (2011). Influences of source - Item contingency and schematic knowledge on source monitoring: Tests of the probability-matching account. *Journal of Memory and Language*, *64*(1), 1-17. https://doi.org/10.1016/j.jml.2010.09.001

Belli, R. F., Lindsay, D. S., Gales, M. S., & McCarthy, T. T. (1994). Memory impairment and source misattribution in postevent misinformation experiments with short retention intervals. *Memory & Cognition*, *22*(1), 40-54. https://doi.org/10.3758/BF03202760

Berlad, I., & Pratt, H. (1995). P300 in response to the subject's own name. *Electroencephalography and Clinical Neurophysiology*, *96*(5), 472-474. https://doi.org/10.1016/0168-5597(95)00116-A

Blank, H., & Launay, C. (2014). How to protect eyewitness memory against the misinformation effect: A meta-analysis of post-warning studies. *Journal of Applied Research in Memory and Cognition*, *3*(2), 77-88. https://doi.org/10.1016/j.jarmac.2014.03.005

Bledowski, C., Prvulovic, D., Hoechstetter, K., Scherg, M., Wibral, M., Goebel, R., & Linden, D. E. (2004). Localizing P300 generators in visual target and distractor processing: A combined event-related potential and functional magnetic resonance imaging study. *Journal of Neuroscience*, *24*(42), 9353-9360. https://doi.org/10.1523/jneurosci.1897-04.2004

Bocquillon, P., Bourriez, J. L., Palmero-Soler, E., Destee, A., Defebvre, L., Derambure, P., & Dujardin, K. (2012). Role of basal ganglia circuits in resisting interference by distracters: A swLORETA study. *PLoS One*, *7*(3), e34239. https://doi.org/10.1371/journal.pone.0034239

Brocke, B., Tasche, K. G., & Beauducel, A. (1997). Biopsychological foundations of extraversion: Differential effort reactivity and state control. *Personality and Individual Differences*, *22*(4), 447-458. https://doi.org/10.1016/S0191-8869(96)00226-7

Brown, S. B., van der Wee, N. J., van Noorden, M. S., Giltay, E. J., & Nieuwenhuis, S. (2015). Noradrenergic and cholinergic modulation of late ERP responses to deviant stimuli. *Psychophysiology*, *52*(12), 1620-1631. https://doi.org/10.1111/psyp.12544

Calvillo, D. P., & Parong, J. A. (2016). The misinformation effect is unrelated to the DRM effect with and without a DRM warning. *Memory*, *24*(3), 324-333. https://doi.org/10.1080/09658211.2015.1005633

Chen, J., Yuan, J., Feng, T., Chen, A., Gu, B., & Li, H. (2011). Temporal features of the degree effect in self-relevance: Neural correlates. *Biological Psychology*, *87*(2), 290-295. https://doi.org/10.1016/j.biopsycho.2011.03.012

Chun, M. M., & Turk-Browne, N. B. (2007). Interactions between attention and memory. *Current Opinion in Neurobiology*, *17*(2), 177-184. https://doi.org/10.1016/j.conb.2007.03.005

Clark, V. P., Fannon, S., Lai, S., Benson, R., & Bauer, L. (2000). Responses to rare visual target and distractor stimuli using event-related fMRI. *Journal of Neurophysiology*, *83*(5), 3133-3139.

Cohen, J., & Polich, J. (1997). On the number of trials needed for P300. *International Journal of Psychophysiology*, *25*(3), 249-255. https://doi.org/10.1016/S0167-8760(96)00743-X

Conroy, M. A., & Polich, J. (2007). Normative variation of P3a and P3b from a large sample: Gender, topography, and response time. *Journal of Psychophysiology*, *21*(1), 22-32. https://doi.org/10.1027/0269-8803.21.1.22

Corbetta, M., Miezin, F. M., Dobmeyer, S., Shulman, G. L., & Petersen, S. E. (1991). Selective and divided attention during visual discriminations of shape, color, and speed: Functional anatomy by positron emission tomography. *Journal of Neuroscience*, *11*(8), 2383-2402.

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience*, *3*(3), 201-215. https://doi.org/10.1038/nrn755

Cortese, S., Castellanos, F. X., Eickhoff, C. R., D'Acunto, G., Masi, G., Fox, P. T., ... Eickhoff, S. B. (2016). Functional decoding and meta-analytic connectivity modeling in adult attention-deficit/hyperactivity disorder. *Biological Psychiatry, 80*(12), 896-904. https://doi.org/10.1016/j.biopsych.2016.06.014

Coull, J. T., Frackowiak, R. S. J., & Frith, C. D. (1998). Monitoring for target objects: Activation of right frontal and parietal cortices with increasing time on task. *Neuropsychologia*, *36*(12), 1325-1334. https://doi.org/10.1016/S0028-3932(98)00035-9

Crottaz-Herbette, S., & Menon, V. (2006). Where and when the anterior cingulate cortex modulates attentional response: Combined fMRI and ERP evidence. *Journal of Cognitive Neuroscience*, *18*(5), 766-780. https://doi.org/10.1162/jocn.2006.18.5.766

Debener, S., Makeig, S., Delorme, A., & Engel, A. K. (2005). What is novel in the novelty oddball paradigm? Functional significance of the novelty P3 event-related potential as revealed by independent component analysis. *Cognitive Brain Research*, *22*(3), 309-321. https://doi.org/10.1016/j.cogbrainres.2004.09.006

Delorme, A., & Makeig, S. (2004). EEGLAB: An open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *Journal of Neuroscience Methods*, *134*(1), 9-21. https://doi.org/10.1016/j.jneumeth.2003.10.009

Dewhurst, S. A., Barry, C., Swannell, E. R., Holmes, S. J., & Bathurst, G. L. (2007). The effect of divided attention on false memory depends on how memory is tested. *Memory & Cognition*, *35*(4), 660-667. https://doi.org/10.3758/BF03193304

Dien, J. (2010a). The ERP PCA Toolkit: An open source program for advanced statistical analysis of event-related potential data. *Journal of Neuroscience Methods*, *187*(1), 138-145. https://doi.org/10.1016/j.jneumeth.2009.12.009

Dien, J. (2010b). Evaluating two-step PCA of ERP data with Geomin, Infomax, Oblimin, Promax, and Varimax rotations. *Psychophysiology*, *47*(1), 170-183. https://doi.org/10.1111/j.1469-8986.2009.00885.x

Donchin, E. (1981). Surprise!… Surprise? *Psychophysiology*, *18*(5), 493-513. https://doi.org/10.1111/j.1469-8986.1981.tb01815.x

Donchin, E., & Coles, M. G. (1988). Is the P300 component a manifestation of context updating? *Behavioral and Brain Sciences*, *11*(3), 357-427. https://doi.org/10.1017/S0140525X00058027

Dywan, J., Segalowitz, S. J., & Webster, L. (1998). Source monitoring: ERP evidence for greater reactivity to nontarget information in older adults. *Brain and Cognition*, *36*(3), 390-430. https://doi.org/10.1006/brcg.1997.0979

Fernandes, M. A., & Moscovitch, M. (2000). Divided attention and memory: Evidence of substantial interference effects at retrieval and encoding. *Journal of Experimental Psychology: General*, *129*(2), 155-176. https://doi.org/10.1037/0096-3445.129.2.155

Fitzgerald, P. G., & Picton, T. W. (1981). Temporal and sequential probability in evoked potential studies. *Canadian Journal of Psychology*, *35*(2), 188-200. https://doi.org/10.1037/h0081154

García-Larrea, L., & Cézanne-Bert, G. (1998). P3, Positive slow wave and working memory load: A study on the functional correlates of slow wave activity. *Electroencephalography and Clinical Neurophysiology*, *108*(3), 260-273. https://doi.org/10.1016/S0168-5597(97)00085-3

Garoff-Eaton, R. J., Slotnick, S. D., & Schacter, D. L. (2006). Not all false memories are created equal: The neural basis of false recognition. *Cerebral Cortex*, *16*(11), 1645-1652. https://doi.org/10.1093/cercor/bhj101

Gevins, A., Smith, M. E., Le, J., Leong, H., Bennett, J., Martin, N., ... Whitfield, S. (1996). High resolution evoked potential imaging of the cortical dynamics of human working memory. *Electroencephalography and Clinical Neurophysiology, 98*(4), 327–348. https://doi.org/10.1016/0013-4694(96)00288-X

Goff, L. M., & Roediger, H. L. (1998). Imagination inflation for action events: Repeated imaginings lead to illusory recollections. *Memory & Cognition*, *26*(1), 20-33. https://doi.org/10.3758/BF03211367

Grahn, J. A., Parkinson, J. A., & Owen, A. M. (2008). The cognitive functions of the caudate nucleus. *Progress in Neurobiology*, *86*(3), 141-155. https://doi.org/10.1016/j.pneurobio.2008.09.004

Grahn, J. A., Parkinson, J. A., & Owen, A. M. (2009). The role of the basal ganglia in learning and memory: Neuropsychological studies. *Behavioural Brain Research*, *199*(1), 53-60. https://doi.org/10.1016/j.bbr.2008.11.020

Gray, H. M., Ambady, N., Lowenthal, W. T., & Deldin, P. (2004). P300 as an index of attention to self-relevant stimuli. *Journal of Experimental Social Psychology*, *40*(2), 216-224. https://doi.org/10.1016/S0022-1031(03)00092-1

Higham, P. A. (1998). Believing details known to have been suggested. *British Journal of Psychology*, *89*(2), 265. https://doi.org/10.1111/j.2044-8295.1998.tb02684.x

Higham, P. A., Blank, H., & Luna, K. (2017). Effects of postwarning specificity on memory performance and confidence in the eyewitness misinformation paradigm. *Journal of Experimental Psychology. Applied*, *23*(4), 417-432. https://doi.org/10.1037/xap0000140

Hoffman, H. G. (1997). Role of memory strength in reality monitoring decisions: Evidence from source attribution biases. *Journal of Experimental Psychology. Learning, Mmory, and Cognition*, *23*(2), 371-383. https://doi.org/10.1037/0278-7393.23.2.371

Hutchinson, J. B., & Turk-Browne, N. B. (2012). Memory-guided attention: Control from multiple memory systems. *Trends in Cognitive Sciences*, *16*(12), 576-579. https://doi.org/10.1016/j.tics.2012.10.003

Inoue, Y., Inagaki, M., Gunji, A., Kokubo, N., & Kaga, M. (2007). Cerebral inhibitory functioning in patients with attention deficit/hyperactivity disorder. I. Analysis of non-target-P300 component in a visual oddball paradigm. *No to Hattatsu*, *39*(4), 263-267.

Johansson, M., Stenberg, G., Lindgren, M., & Rosén, I. (2002). Memory for perceived and imagined pictures: An event-related potential study. *Neuropsychologia*, *40*(7), 986-1002. https://doi.org/10.1016/S0028-3932(01)00148-8

Johnson, R., & Donchin, E. (1985). Second thoughts: Multiple P300s elicited by a single stimulus. *Psychophysiology*, *22*(2), 182-194. https://doi.org/10.1111/j.1469-8986.1985.tb01584.x

Jonkman, L. M., Kemner, C., Verbaten, M. N., Koelega, H. S., Camfferman, G., v d Gaag, R.-J., ... van Engeland, H. (1997). Event-related potentials and performance of attention-deficit hyperactivity disorder: Children and normal controls in auditory and visual selective attention tasks. *Biological Psychiatry, 41*(5), 595-611. https://doi.org/10.1016/S0006-3223(96)00073-X

Kiat, J. E., & Belli, R. F. (2017). An exploratory high-density EEG investigation of the misinformation effect: Attentional and recollective differences between true and false perceptual memories. *Neurobiology of Learning and Memory*, *141*, 199-208. https://doi.org/10.1016/j.nlm.2017.04.007

Kiat, J.E. (2018). Assessing cross-modal target transition effects with a visual-auditory oddball. *International Journal of Psychophysiology*, 129, 58-66. https://doi.org/10.1016/j.ijpsycho.2018.04.010

Kiehl, K. A., Laurens, K. R., Duty, T. L., Forster, B. B., & Liddle, P. F. (2001). An event-related fMRI study of visual and auditory oddball tasks. *Journal of Psychophysiology*, *15*(4), 221-240. https://doi.org/10.1027/0269-8803.15.4.221

Kiehl, K. A., Stevens, M. C., Laurens, K. R., Pearlson, G., Calhoun, V. D., & Liddle, P. F. (2005). An adaptive reflexive processing model of neurocognitive function: Supporting evidence from a large scale (n = 100) fMRI study of an auditory oddball task. *NeuroImage*, *25*(3), 899-915. https://doi.org/10.1016/j.neuroimage.2004.12.035

Kim, H. (2014). Involvement of the dorsal and ventral attention networks in oddball stimulus processing: A meta-analysis. *Human Brain Mapping*, *35*(5), 2265-2284. https://doi.org/10.1002/hbm.22326

Kok, A. (2001). On the utility of P3 amplitude as a measure of processing capacity. *Psychophysiology*, *38*(3), 557-577. https://doi.org/10.1017/S0048577201990559

Kok, A., & de Jong, H. L. (1980). The effect of repetition of infrequent familiar and unfamiliar visual patterns on components of the event-related brain potential. *Biological Psychology*, *10*(3), 167-188. https://doi.org/10.1016/0301-0511(80)90013-7

Lane, S. M. (2006). Dividing attention during a witnessed event increases eyewitness suggestibility. *Applied Cognitive Psychology*, *20*(2), 199-212. https://doi.org/10.1002/acp.1177

Lawrence, N. S., Ross, T. J., Hoffmann, R., Garavan, H., & Stein, E. A. (2003). Multiple neuronal networks mediate sustained attention. *Journal of Cognitive Neuroscience*, *15*(7), 1028-1038. https://doi.org/10.1162/089892903770007416

Li, Y., Wang, L. Q., & Hu, Y. (2009). Localizing P300 generators in high-density event- related potential with fMRI. *Medical Science Monitor*, *15*(3), 47-53.

Lindner, I., Echterhoff, G., Davidson, P. S. R., & Brand, M. (2010). Observation inflation: Your actions become mine. *Psychological Science*, *21*(9), 1291-1299. https://doi.org/10.1177/0956797610379860

Loftus, E. (2003). Science and society: Our changeable memories: Legal and practical implications. *Nature Reviews Neuroscience*, *4*(3), 231. https://doi.org/10.1038/nrn1054

Loveless, N. E., Simpson, M., & Naatanen, R. (1987). Frontal negative and parietal positive components of the slow wave dissociated. *Psychophysiology*, *24*(3), 340-345. https://doi.org/10.1111/j.1469-8986.1987.tb00305.x

Lütkenhöner, B. (1998). Dipole source localization by means of maximum likelihood estimation. I. Theory and simulations. *Electroencephalography and Clinical Neurophysiology*, *106*(4), 314-321. https://doi.org/10.1016/S0013-4694(97)00140-5

Macmillan, N. A. (2005). Detection theory : A user's guide / Neil A. MacMillan and C. Douglas Creelman (pp. 1). Mahwah, N.J.: Lawrence Erlbaum.

MacRae, C. N., Schloerscheidt, A. M., Bodenhausen, G. V., & Milne, A. B. (2002). Creating memory illusions: Expectancy-based processing and the generation of false memories. *Memory*, *10*(1), 63-80. https://doi.org/10.1080/09658210143000254

Mantini, D., Corbetta, M., Perrucci, M. G., Romani, G. L., & Del Gratta, C. (2009). Large-scale brain networks account for sustained and transient activity during target detection. *NeuroImage*, *44*(1), 265-274. https://doi.org/10.1016/j.neuroimage.2008.08.019

McDonald, C. G., Gabbay, F. H., Rietschel, J. C., & Duncan, C. C. (2010). Evidence for a new late positive ERP component in an attended novelty oddball task. *Psychophysiology*, *47*(5), 809-813. https://doi.org/10.1111/j.1469-8986.2010.00986.x

Mendez, M. F., Adams, N. L., & Lewandowski, K. S. (1989). Neurobehavioral changes associated with caudate lesions. *Neurology, 39*(3), 349-354. https://doi.org/10.1212/WNL.39.3.349

Mesulam, M. M. (1999). Spatial attention and neglect: Parietal, frontal and cingulate contributions to the mental representation and attentional targeting of salient extrapersonal events. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *354*(1387), 1325-1346. https://doi.org/10.1098/rstb.1999.0482

Mitchell, K. J., Johnson, M. K., & Mather, M. (2003). Source monitoring and suggestibility to misinformation: Adult age-related differences. *Applied Cognitive Psychology*, *17*(1), 107-119. https://doi.org/10.1002/acp.857

Montes, L. G. A., Ricardo-Garcell, J., De La Torre, L. B., Alcántara, H. P., García, R. B. M., Fernández-Bouzas, A., & Acosta, D. Á. (2010). Clinical correlations of grey matter reductions in the caudate nucleus of adults with attention deficit hyperactivity disorder. *Journal of Psychiatry & Neuroscience*, *35*(4), 238-246. https://doi.org/10.1503/jpn.090099

Mulert, C., Pogarell, O., Juckel, G., Rujescu, D., Giegling, I., Rupp, D., ... Hegerl, U. (2004). The neural basis of the P300 potential. Focus on the time-course of the underlying cortical generators. *European Archives of Psychiatry and Clinical Neuroscience, 254*(3), 190-198. https://doi.org/10.1007/s00406-004-0469-2

Murphy, G., & Greene, C. M. (2016). Perceptual load affects eyewitness accuracy and susceptibility to leading questions. *Frontiers in Psychology*, *7*, 1322. https://doi.org/10.3389/fpsyg.2016.01322

Okado, Y., & Stark, C. E. L. (2005). Neural activity during encoding predicts false memories created by misinformation. *Learning & Memory*, *12*(1), 3-11. https://doi.org/10.1101/lm.87605

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia*, *9*(1), 97-113. https://doi.org/10.1016/0028-3932(71)90067-4

Oostenveld, R., Fries, P., Maris, E., & Schoffelen, J.-M. (2011). FieldTrip: Open source software for advanced analysis of MEG, EEG, and invasive electrophysiological data. *Computational Intelligence and Neuroscience*, 1-9. https://doi.org/10.1155/2011/156869

Palmer, M. A., Brewer, N., McKinnon, A. C., & Weber, N. (2010). Phenomenological reports diagnose accuracy of eyewitness identification decisions. *Acta Psychologica*, *133*(2), 137-145. https://doi.org/10.1016/j.actpsy.2009.11.002

Perez-Mata, M. N., Read, J. D., & Diges, M. (2002). Effects of divided attention and word concreteness on correct recall and false memory reports. *Memory*, *10*(3), 161-177. https://doi.org/10.1080/09658210143000308

Petersen, S. E., & Posner, M. I. (2012). The attention system of the human brain: 20 years after. *Annual Review of Neuroscience*, *35*, 73-89. https://doi.org/10.1146/annurev-neuro-062111-150525

Polak, M., Dukała, K., Szpitalak, M., & Polczyk, R. (2016). Toward a non-memory misinformation effect: Accessing the original source does not prevent yielding to misinformation. *Current Psychology*, *35*(1), 1-12. https://doi.org/10.1007/s12144-015-9352-8

Polich, J. (2007). Updating P300: An integrative theory of P3a and P3b. *Clinical Neurophysiology*, *118*(10), 2128-2148. https://doi.org/10.1016/j.clinph.2007.04.019

Posner, M. I., & Petersen, S. E. (1990). The attention system of the human brain. *Annual Review of Neuroscience*, *13*, 25-42. https://doi.org/10.1146/annurev.ne.13.030190.000325

Ritter, W., & Ruchkin, D. S. (1992). A review of event-related potential components discovered in the context of studying P3. In D. Friedman, G. E. Bruder, D. Friedman & G. E. Bruder (Eds.), *Psychophysiology and experimental psychopathology: A tribute to Samuel Sutton.* (Vol. 658, pp. 1-32). New York, NY, US: New York Academy of Sciences. https://doi.org/10.1111/j.1749-6632.1992.tb22837.x

Rivardo, M. G., Brown, K. A., Rodgers, A. D., Maurer, S. V., Camaione, T. C., Minjock, R. M., & Gowen, G. M. (2011). Integrating inattentional blindness and eyewitness memory. *North American Journal of Psychology*, *13*(3), 519-538.

Robertson, I. H., Manly, T., Andrade, J., Baddeley, B. T., & Yiend, J. (1997). 'Oops!': Performance correlates of everyday attentional failures in traumatic brain injured and normal subjects. *Neuropsychologia*, *35*(6), 747-758.

Roediger, H. L., & McDermott, K. B. (1995). Creating false memories: Remembering words not presented in lists. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *21*(4), 803-814. https://doi.org/10.1037/0278-7393.21.4.803

Rosenfeld, J. P., Bhat, K., Miltenberger, A., & Johnson, M. (1992). Event-related potentials in the dual task paradigm: P300 discriminates engaging and non-engaging films when film-viewing is the primary task. *International Journal of Psychophysiology*, *12*(3), 221-232.

Rosler, F., & Heil, M. (1991). Toward a functional categorization of slow waves: Taking into account past and future events. *Psychophysiology*, *28*(3), 344-358. https://doi.org/10.1111/j.1469-8986.1991.tb02205.x

Rozenkrants, B., & Polich, J. (2008). Affective ERP processing in a visual oddball task: Arousal, valence, and gender. *Clinical Neurophysiology*, *119*(10), 2260-2265. https://doi.org/10.1016/j.clinph.2008.07.213

Ruchkin, D. S., & Sutton, S. (1983) Positive slow wave and P300: Association and disassociation. *Advances in Psychology*, *10*, 233-250. https://doi.org/10.1016/S0166-4115(08)62042-7

Ruchkin, D. S., Sutton, S., Kietzman, M. L., & Silver, K. (1980). Slow wave and P300 in signal detection. *Electroencephalography and Clinical Neurophysiology*, *50*(1), 35-47. https://doi.org/10.1016/0013-4694(80)90321-1

Rummel, J., Smeekens, B. A., & Kane, M. J. (2017). Dealing with prospective memory demands while performing an ongoing task: Shared processing, increased on-task focus, or both? *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *43*(7), 1047-1062. https://doi.org/10.1037/xlm0000359

Rushby, J. A., Barry, R. J., & Doherty, R. J. (2005). Separation of the components of the late positive complex in an ERP dishabituation paradigm. *Clinical Neurophysiology*, *116*(10), 2363-2380. https://doi.org/10.1016/j.clinph.2005.06.008

Russo, P. M., De Pascalis, V., Varriale, V., & Barratt, E. S. (2008). Impulsivity, intelligence and P300 wave: An empirical study. *International Journal of Psychophysiology*, *69*(2), 112-118. https://doi.org/10.1016/j.ijpsycho.2008.03.008

Sauer, J., & Hope, L. (2016). The effects of divided attention at study and reporting procedure on regulation and monitoring for episodic recall. *Acta Psychologica*, *169*, 143-156. https://doi.org/10.1016/j.actpsy.2016.05.015

Schooler, J. W., Gerhard, D., & Loftus, E. F. (1986). Qualities of the unreal. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *12*(2), 171-181. https://doi.org/10.1037/0278-7393.12

Schrimsher, G. W., Billingsley, R. L., Jackson, E. F., & Moore, B. D., 3rd. (2002). Caudate nucleus volume asymmetry predicts attention-deficit hyperactivity disorder (ADHD) symptomatology in children. *Journal of Child Neurology*, *17*(12), 877-884. https://doi.org/10.1177/08830738020170122001

Skinner, E. I., & Fernandes, M. A. (2009). Illusory recollection in older adults and younger adults under divided attention. *Psychology and Aging*, *24*(1), 211-216. https://doi.org/10.1037/a0014177

Spencer, K. M., Dien, J., & Donchin, E. (2001). Spatiotemporal analysis of the late ERP responses to deviant stimuli. *Psychophysiology*, *38*(2), 343-358. https://doi.org/10.1111/1469-8986.3820343

Squires, N. K., Squires, K. C., & Hillyard, S. A. (1975). Two varieties of long-latency positive waves evoked by unpredictable auditory stimuli in man. *Electroencephalography and Clinical Neurophysiology*, *38*(4), 387-401. https://doi.org/10.1016/0013-4694(75)90263-1

Steiner, G. Z., Barry, R. J., & Gonsalvez, C. J. (2013). Can working memory predict target-to-target interval effects in the P300? *International Journal of Psychophysiology*, *89*(3), 399-408. https://doi.org/10.1016/j.ijpsycho.2013.07.011

Stelmack, R. M., & Sculthorpe, L. D. (2008). Mental ability and individual differences in P300 and mismatch negativity. *International Journal of Psychophysiology*, *69*(3), 158. https://doi.org/10.1016/j.ijpsycho.2008.05.402

Stevens, M. C., Calhoun, V. D., & Kiehl, K. A. (2005). fMRI in an oddball task: Effects of target-to-target interval. *Psychophysiology*, *42*(6), 636-642. https://doi.org/10.1111/j.1469-8986.2005.00368.x

Stokes, M. G., Atherton, K., Patai, E. Z., & Nobre, A. C. (2012). Long-term memory prepares neural activity for perception. *Proceedings of the National Academy of Sciences*, *109*(6), E360–E367. https://doi.org/10.1073/pnas.1108555108

Strobel, A., Debener, S., Sorger, B., Peters, J. C., Kranczioch, C., Hoechstetter, K., ... Goebel, R. (2008). Novelty and target processing during an auditory novelty oddball: A simultaneous event-related potential and functional magnetic resonance imaging study. *NeuroImage, 40*(2), 869-883. https://doi.org/10.1016/j.neuroimage.2007.10.065

Struber, D., & Polich, J. (2002). P300 and slow wave from oddball and single-stimulus visual tasks: Inter-stimulus interval effects. *International Journal of Psychophysiology*, *45*(3), 187-196. https://doi.org/10.1016/S0167-8760(02)00071-5

Sutton, S., Braren, M., Zubin, J., & John, E. R. (1965). Evoked-potential correlates of stimulus uncertainty. *Science*, *150*(3700), 1187-1188. https://doi.org/10.1126/science.150.3700.1187

Tousignant, J. P., Hall, D., & Loftus, E. F. (1986). Discrepancy detection and vulnerability to misleading postevent information. *Memory & Cognition*, *14*(4), 329-338. https://doi.org/10.3758/bf03202511

Uncapher, M. R., & Rugg, M. D. (2005). Effects of divided attention on fMRI correlates of memory encoding. *Journal of Cognitive Neuroscience*, *17*(12), 1923-1935. https://doi.org/10.1162/089892905775008616

Unsworth, N., & Robison, M. K. (2016). The influence of lapses of attention on working memory capacity. *Memory & Cognition*, *44*(2), 188-196. https://doi.org/10.3758/s13421-015-0560-0

Volpe, U., Mucci, A., Bucci, P., Merlotti, E., Galderisi, S., & Maj, M. (2007). The cortical generators of P3a and P3b: A LORETA study. *Brain Research Bulletin*, *73*(4-6), 220-230. https://doi.org/10.1016/j.brainresbull.2007.03.003

Walz, J. M., Goldman, R. I., Carapezza, M., Muraskin, J., Brown, T. R., & Sajda, P. (2013). Simultaneous EEG-fMRI reveals temporal evolution of coupling between supramodal cortical attention networks and the brainstem. *Journal of Neuroscience*, *33*(49), 1912-1922. https://doi.org/10.1523/jneurosci.2649-13.2013

Whitmer, A. J., & Gotlib, I. H. (2013). An attentional scope model of rumination. *Psychological Bulletin*, *139*(5), 1036-1061. https://doi.org/10.1037/a0030923

Williams, L. M., Simms, E., Clark, C. R., Paul, R. H., Rowe, D., & Gordon, E. (2005). The test-retest reliability of a standardized neurocognitive and neurophysiological test battery: "Neuromarker". *International Journal of Neuroscience*, *115*(12), 1605-1630. https://doi.org/10.1080/00207450590958475

Wronka, E., Kaiser, J., & Coenen, A. M. (2012). Neural generators of the auditory evoked potential components P3a and P3b. *Acta Neurobiologiae Experimentalis*, *72*(1), 51-64.

Yurgil, K. A., & Golob, E. J. (2013). Cortical potentials in an auditory oddball task reflect individual differences in working memory capacity. *Psychophysiology*, *50*(12), 1263-1274. https://doi.org/10.1111/psyp.12140

Zaragoza, M. S., & Lane, S. M. (1998). Processing resources and eyewitness suggestibility. *Legal and Criminological Psychology*, *3*(2), 305-320. https://doi.org/10.1111/j.2044-8333.1998.tb00368.x

Zhao, W., & Li, A. X. (2012). A generalized approach to estimating sample sizes. Los Angeles, CA: SAS Institute Inc.