

Electrophysiological Correlates of the Continued Influence Effect of Misinformation: An  
Exploratory Study

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### Abstract

Misinformation often affects inferential reasoning even after it has been retracted. This is known as the continued influence effect (CIE). Previous behavioural research into the effect's underlying mechanisms has focussed on the role of long-term memory processes at the time misinformation is retrieved during inferential reasoning. We present the first investigation into the CIE using event-related potentials (ERPs). Participants completed a continued-influence task whilst electroencephalographic data were recorded. Analysis was guided by previous ERP research investigating post-event misinformation effects. ERPs elicited for retracted misinformation were more negative at a frontal-midline region of interest (300-500 ms) and more positive at a left-parietal region (450-600 ms) compared to correctly-accepted true information, though no differences were observed between rejected and accepted misinformation. This suggests that post-retraction reliance on misinformation may be driven by particularly strong recollection of the misinformation, ostensibly following poor integration of the retraction into the initial, partially invalid mental model.

**Keywords:** Continued influence effect; Misinformation; Memory updating; Retrieval; ERP

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When individuals are provided with misinformation—for example, incorrect information regarding the cause of an event—their memory, inferential reasoning, and decision making may still be influenced by the misinformation even after it has been retracted; this phenomenon is known as the continued influence effect (CIE; Johnson & Seifert, 1994; Lewandowsky, Ecker, Seifert, Schwarz, & Cook, 2012; Walter & Tukachinsky, 2020). At the core of theorising regarding this effect lies the assertion that information once encoded into memory cannot simply be erased or overwritten, such that there is always the potential of information to be reactivated even after a retraction or correction has been processed. Thus, previous behavioural research has theorised that the CIE occurs at least partially as a result of memory retrieval processes.

More specifically, a retrieval-failure account (Ecker, Lewandowsky, & Tang, 2010; Swire, Ecker, & Lewandowsky, 2017) has proposed that both valid and invalid memory entries simultaneously compete for activation during retrieval (Ayers & Reder, 1998). Thus, a relevant retrieval cue could activate, potentially through automatic familiarity-based processes, a piece of plausible misinformation stored within an otherwise valid event representation (Gordon, Quadflieg, Brooks, Ecker, & Lewandowsky, 2019). If this occurs in the context of an inferential reasoning task, strategic monitoring processes and recollection of the retraction will be required to prevent the activated misinformation from influencing the reasoning process. If these strategic memory processes fail, however, reliance on misinformation may occur. One variant of the retrieval-failure account assumes that retractions lead to a piece of stored misinformation being “tagged” as incorrect (Gilbert, Krull, & Malone, 1990). If this retraction tag is not recovered during memory retrieval

alongside the misinformation, then the misinformation may influence the reasoning process (Ecker, Lewandowsky, Swire, & Chang, 2011; Mayo, Schul, & Burnstein, 2004).

One way to test this account is through an investigation of neuropsychological markers of memory retrieval, such as the electrophysiological correlates established by previous event-related potential (ERP) research. This was the theoretical motivation of the present study. Previous research on memory retrieval processes has theorised a dual-process model of familiarity and recollection (Rugg & Curran, 2007; Yonelinas, 1999, 2002), and ERP research has suggested distinct electrophysiological indices for each of these: First, the FN400 (a frontal negativity occurring approximately 300 to 500 ms post-stimulus onset) has been found to be associated with familiarity-based processes during recognition, with familiar stimuli eliciting a less pronounced (more positive) waveform. Second, a parietal positivity occurring between approximately 400 and 700 ms post-stimulus onset—the late positive complex (LPC)—has been linked to recollection processes, with recollected stimuli eliciting a more pronounced (more positive) waveform (e.g., Curran, 2000; Friedman & Johnson, 2000; Trott, Friedman, Ritter, Fabiani, & Snodgrass, 1999; Wilding, Doyle, & Rugg, 1995; Zimmer & Ecker, 2010). To illustrate, such ‘old/new’ effects were demonstrated in the domain of verbal memory by Strózak, Bird, Corby, Frishkoff, and Curran (2016): when participants were shown words they had not previously seen (and correctly identified them as new), the FN400 component was more negative for these new words than for words previously displayed. Likewise, the LPC was more positive for old recognised words than new words. To the extent that the CIE arises as a consequence of retrieval processing, it may thus be the case that these ERP indices of memory retrieval processes are modulated during the test phase of the CIE paradigm.

Some findings from the recognition memory literature support this assumption. For example, Nessler and Mecklinger (2003) reported that both FN400 and LPC components

were attenuated for incorrect recognition (false alarms) of lures that were semantically-related to target words (also see Wolk et al., 2006). In studies involving the directed forgetting of items, a reduction and even a reversal of the LPC for successfully-forgotten items has been reported, interpreted as evidence for retrieval inhibition (Nowicka, Jednoróg, Wypych, & Marchewka, 2009; Paz-Caballero & Menor, 1999; Ullsperger, Mecklinger, & Müller, 2000; Van Hooff, Whitaker, & Ford, 2009).

Another ERP component potentially of interest is the P300, a peak that occurs around 300 ms post-stimulus onset at parietal scalp sites, which is associated with the updating of information in memory (for a review, see Polich, 2007). According to the context updating account (Donchin & Coles, 1988), the P300 component is enhanced when incoming information is particularly salient. In the recognition memory literature, previous ERP research has found that the P300 amplitude is enhanced when pre-activated contextual expectations closely match with presented stimuli (Molinaro & Carreiras, 2010). In the CIE paradigm, the amplitude of the P300 component may therefore be an index of how well the misinformation retraction has been integrated into a mental event model, which may in turn make a reference to previously retracted misinformation during test relatively unexpected.

To the best of our knowledge, only a very limited amount of ERP research has investigated misinformation processing, and no previous research has examined the electrophysiology of misinformation processing within the CIE paradigm (for some relevant fMRI work, see Gordon, Brooks, Quadflieg, Ecker, & Lewandowsky, 2017; Gordon et al., 2019; Karanian & Slotnick, 2017). Some limited ERP research has investigated the impact of *post-event* misinformation on memory retrieval—in the post-event paradigm, as opposed to the CIE paradigm, participants initially encode valid event information, and misinformation subsequently provided to them influences memory for the event (e.g., Loftus, 2005; Meek, Phillips, Boswell, & Vendemia, 2013; for a behavioural study combining both CIE and post-

event paradigms, see Ecker et al., 2015). For example, Kiat and Belli (2017) found that electrophysiological activity at left parieto-occipital scalp sites was modulated by task condition in a post-event paradigm. Specifically, P300 and LPC amplitudes were significantly larger when accepting true memories relative to rejecting false ones, and false memory rejections elicited a larger P300 amplitude in comparison to false memory endorsements. That is, P300 amplitude was greatest when elicited by acceptance of true memories, significantly smaller for correctly rejected misinformation, and smaller still for incorrectly endorsed misinformation. Recent research by Volz, Stark, Vaitl, and Ambach (2019) also examined ERP components elicited by a post-event misinformation task and found that both true and false memories elicited more positive FN400 amplitudes than correct rejections, implying a familiarity effect during the processing of misinformation. Additionally, both the parietal P300 and LPC components appear to be associated with subjectively experienced memory (Goldmann et al., 2003), suggesting that parietal activity may be indicative of whether a memory is subjectively believed to be true, rather than whether it is objectively accurate.

To summarize, a small body of ERP research has examined misinformation processing through a post-event misinformation paradigm, and has reported modulations in amplitude of the FN400 (Volz et al., 2019), a frontal ERP component thought to be associated with familiarity in memory, and the P300 and/or LPC components (Kiat & Belli, 2017; Volz et al., 2019) at left/midline parietal scalp sites, theorised to be associated with context updating in memory and recollection, respectively. No research to date has investigated misinformation processing in the CIE paradigm, and no previous research has investigated response-locked electrophysiological activity elicited as a result of misinformation processing.

The aim of the current study was to investigate the electrophysiological correlates of the CIE—that is, the incorrect acceptance of retracted misinformation as valid. We focused on retractions—mere negations of misinformation—rather than more thorough refutations, as well-designed refutations that provide alternative factual information and explain why the misinformation is false tend to achieve greater CIE reduction (e.g., see Ecker, O’Reilly, Reid, & Chang, 2020; Paynter et al., 2019; Swire et al., 2017; Walter & Tukachinsky, 2020). This would have resulted in a low number of trials with incorrect misinformation acceptance.

It was hypothesised that to the extent that memory retrieval failures contribute to the CIE (Ecker et al., 2010; Swire et al., 2017), electrophysiological activity at frontal and/or left-parietal regions would be modulated by task condition in a CIE paradigm. Given that ERP research on the CIE paradigm has never been conducted before, the direction of such modulations was difficult to predict. On the one hand, it might be the case that retracted misinformation is only accepted as true if the misinformation is retrieved with particular strength and high fidelity. This view would predict that incorrect acceptance of retracted misinformation may be accompanied by more positive activity (in the FN400 but potentially also the parietal components) relative to correct rejection of retracted misinformation and/or correct acceptance of non-retracted information. On the other hand, it could be argued that correct rejection of misinformation may require additional retrieval of the retraction over and above the information required to accept non-retracted information or incorrectly accept retracted misinformation (i.e., retrieval of additional information is required in order to successfully avoid reliance on misinformation). This view would predict that incorrect acceptance of retracted misinformation (and correct acceptance of non-retracted information) may be accompanied by more negative activation (especially in the parietal LPC) relative to correct rejection of retracted misinformation, akin to “recall-to-reject” processing (see Clark & Gronlund, 1996; Rotello & Heit, 2000) and in line with the findings of attenuated old/new

effects for false alarms and successfully-forgotten items in recognition memory studies. Lastly, given the lack of previous research into response-locked electrophysiological activity in misinformation processing, no specific predictions were made regarding any between-conditions differences: These analyses were purely exploratory.

## Method

### Participants

Participants were 47 undergraduate students from the University of Western Australia who all reported normal or corrected-to-normal vision and no history of neurological disorders (26 female, 21 male; 40 right-handed; age  $M = 21.0$  years,  $SD = 6.1$ , range 18-43). Participants received course credit for participation. After excluding participants with too few trials (see below), 36 participants remained (19 female, 17 male; 32 right-handed; age  $M = 20.1$  years,  $SD = 4.8$ , range = 18-43).

### Materials and Procedure

The misinformation task (see Figure 1) was similar to that used by Gordon et al. (2017) and was administered through ePrime 2.0 (Psychology Software Tools, Inc., Pittsburgh, PA; <http://www.pstnet.com/eprime>). The task consisted of 70 trials. On each trial, the participant was required to read a brief, fictional news report, complete five word/non-word categorisations as a distractor task, and then answer two true/false questions about the news report. The news reports were similar to those previously used in behavioural and neuroimaging studies of the CIE (e.g., Gordon et al., 2017; Ecker, Hogan, & Lewandowsky, 2017; Johnson & Seifert, 1994). Each news report was five sentences long, with sentences presented one at a time. In 50 out of the 70 trials, sentence 2 contained a piece of critical misinformation relating to the cause of the event, which was retracted in sentence 4; this was the misinformation condition. In the remaining 20 trials, there was no retraction; this was the control condition. On some control trials, sentence 2 also contained information relating to

the event cause, on other control trials the event cause was introduced in a different sentence and sentence 2 contained only arbitrary contextual information of little relevance; in either case, the information presented in sentence 4 of the control condition had no bearing on the information presented in sentence 2. Thus, misinformation was presented and retracted in 50 of the 70 trials, and no misinformation was presented in the remaining 20 trials. In both conditions, sentences 1, 3, and 5 only presented arbitrary contextual information. Each sentence was presented on screen for 3,500 ms, with 500 ms between the offset of the previous sentence and the onset of the next. Each participant received the same trials, but in a fully randomised order. Table 1 provides an example of a report for each condition.

After each news report, participants completed five word/non-word judgements as a distractor task, then answered two true/false comprehension questions. The first question was a comprehension question based on information presented in either sentence 1, 3, or 5, and thus concerned a factual detail unrelated to the critical information presented in sentences 2 and 4. The second question related to the critical information presented in sentences 2 and 4. In the misinformation condition, this question involved making a judgement regarding the cause of the event based on the evidence provided, and was thus designed to measure participants' reliance on the retracted misinformation. In the control condition, the second question simply acted as another comprehension question. For both these questions, all but the final word of the question were presented for 2,000 ms before the final, key word appeared on screen to complete the sentence (e.g., "The plane was evacuated because of...FIRE." See Table 1). The first part of the sentence was presented in black lowercase font, centrally in the upper half of the screen, and the keyword was presented in black capital letters centrally in the lower half of the screen. The complete sentence remained on screen until participants responded via keypress on a standard QWERTY keyboard, using "Q" to indicate acceptance of the statement as true, and "P" to indicate rejection of a statement as

false. The purpose of separating the final, key word from the remainder of the sentence was to enable time-locking of the electrophysiological activity to the onset of the key word. The computer screen was blank for 1,000 ms from the response of the second question until the beginning of the following trial.

*Figure 1.* Paradigm diagram of the continued influence effect task used in the current study.

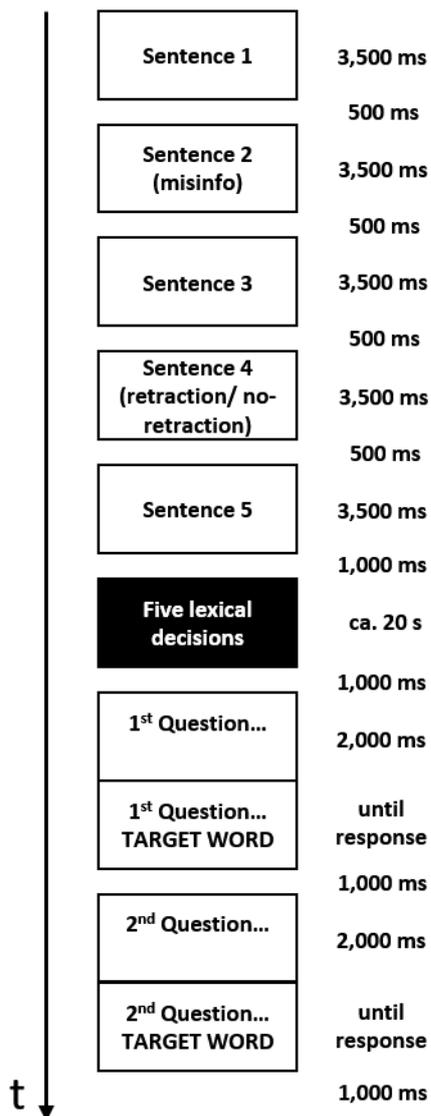


Table 1

*Example Materials for Misinformation and Control Conditions.*

	Misinformation Condition	Control Condition
<b>Example news reports</b>		
Sentence 1	Flight 9035 from Chicago to L.A. was evacuated before take-off yesterday.	An explosion in Kabul, Afghanistan, killed 13 people and injured hundreds.
Sentence 2	The flight crew said that the evacuation was due to a fire in the engine bay.	The explosion was reported to be from the detonation of a bomb.
Sentence 3	Passengers were asked to return to the terminal and await further news.	The blast occurred at 10am in a popular market in the city's centre.
Sentence 4	Fire crews at the scene stated that there was no evidence of a fire.	Kabul has long been a target for terrorism due to political instability.
Sentence 5	The flight was eventually cancelled and passengers were recompensed.	The government announced measures to prevent such incidents in the future.
<b>Example comprehension probes</b>		
Question 1	The flight was travelling to...L.A.	The incident in question involved an...EXPLOSION.
Question 2	The plane was evacuated because of...FIRE.	The explosion was caused by a...BOMB.

### **Electrophysiological Acquisition**

The EEG was continuously recorded with BioSemi 64 channel-electrodes (10/20 system; Ag-AgCl active-electrodes, BioSemi, Amsterdam, NL) at a sampling rate of 512 Hz. Electrodes were placed at 64 scalp sites mounted on an elastic headcap (EEG BioSemi Head-Cap<sup>TM</sup>). During recording, the common mode sense and driven right leg were used as the reference and ground electrodes. Electrodes were connected to the EEG amplifier (BioSemi Active Two AD-box). The digital outputs of all the AD converters were digitally multiplexed and sent via a single optical fibre to a USB2 Receiver (BioSemi) connected to a PC, where the data were registered and stored by means of acquisition software (BioSemi ActiveView 706). To maximise the conductivity and reduce the impedance, an electrode gel (Sigma-gel Parker laboratories, Inc. Fairfield, New Jersey) was applied to each electrode tip.

EEG data were processed using MATLAB 2016a (Mathworks, Natick, MA) through a pipeline utilising EEGLAB 14.0.0 (Delorme & Makeig, 2004) and ERPLab 7.0.0 (Lopez-Calderon & Luck, 2014). Preprocessing was performed by down-sampling the data to 250 Hz, re-referencing to a common average, and applying a bandpass filter to the data (0.1 – 30 Hz). Channels with kurtosis greater than 5 were removed and interpolated. For stimulus-locked analyses (i.e., activity following the presentation of the keyword of question 2), the data were then epoched to 100 ms prior to the presentation onset of the misinformation-question key word to 1,000 post key-word onset, with -100 to 0 ms baseline correction. The Automatic Artifact Removal toolbox (Gómez-Herrero et al., 2006) was then used to remove ocular and electromyographic artifacts using spatial filtering and blind source separation. Two regions of interest (ROIs) were created, based on Kiat and Belli (2017), Stróžak, Bird et al. (2016), and Volz et al. (2019): a frontal ROI, by averaging activity over the Fz, F1, F2, F3, and F4 electrodes, and a left-parietal ROI, by averaging activity over the P1, P3, P5, and PO3 electrodes. Any epochs containing activity greater than  $\pm 150 \mu\text{V}$  at any of these nine electrodes were removed from analyses. In order to avoid unreliable mean waveforms, participants who had fewer than eight epochs in any condition were removed from analyses, as these participants were considered to have an unacceptably low signal-to-noise ratio (Luck, 2014). Although this is quite a low cut-off point, it has been argued that late slow ERP components can be reliably quantified with as few as eight trials (Moran, Jendrusina, & Moser, 2013). As a result, 11 participants were excluded, and the final sample size for analyses was thus  $N = 36$ .

Pre-processing for the response-locked analyses was the same as for the stimulus-locked analyses, except that the data were epoched to 600 ms before the response to question 2 to 400 ms post-response with -600 to -400 ms baseline correction. Additionally, a different,

central-parietal ROI was used, by averaging activity over the Pz, P1, P2, P3, and P4 electrodes, due to potential laterality effects from button presses with different hands.

We calculated ERPs in three conditions: Firstly, the control condition included correct acceptance of non-retracted critical information (“hits” in recognition-memory terms; incorrect rejections of non-retracted information [“misses”] were rare, and discarded). Secondly, the rejection condition included correct rejections of retracted misinformation. Finally, the acceptance condition included incorrect endorsements of statements featuring retracted misinformation (“false alarms”). Three time windows were defined, based on previous literature: For the stimulus-locked ERP components, the FN400 was calculated as the mean amplitude between 300-500 ms (Stróžak, Bird et al., 2016; Volz et al., 2019) at the frontal ROI, and the P300 and LPC components were calculated as the mean amplitudes between 300-400 ms and 450-600 ms (Kiat & Belli, 2017), respectively, at the left-parietal ROI. Visual inspection of these waveforms was also applied to determine whether these windows were suitable in terms of clear peaks and/or between-conditions differences being apparent. This did not suggest any obvious between-conditions differences being missed by only examining these ROIs in these time windows.

For the response-locked ERPs, difference waveforms were calculated at each ROI by subtracting the control condition waveform from the rejection and acceptance conditions, respectively. Significance was established by comparing the amplitude of the difference waveforms at each time point from -200 – 400 ms against a mean value of zero. To control for the number of comparisons conducted, we required a successive sequence of 12 statistically significant values based on an autocorrelation of 0.9 and graphical threshold of 0.05, as detailed by Guthrie and Buchwald (1991).

A one-way repeated-measures ANOVA was conducted for each ERP component to investigate potential differences in mean amplitude between conditions, and Spearman rank

correlations were computed between accuracy and condition amplitude to assess brain-behaviour associations (Rousselet & Pernet, 2012). Paired-samples *t*-tests and Cohen's *d* were calculated to analyse the accuracy of responses to the two true/false questions that participants answered at the end of each trial (i.e., accuracy in the control condition vs. accuracy in the misinformation condition). If the task worked as expected, accuracy on the first question (the comprehension question) should not differ substantially between conditions. However, accuracy on the second question (the misinformation probe in the misinformation condition) should be substantially lower in the misinformation condition. A one-way repeated-measures ANOVA was also conducted on median reaction time for question 2 between conditions.

## Results

### Behavioural Results

Accuracy when responding to the first question (i.e., comprehension question, regardless of condition) was slightly higher in the control condition ( $M = 83.47\%$ ,  $SD = 12.24\%$ ) than the misinformation condition ( $M = 77.67\%$ ,  $SD = 9.85\%$ ),  $t(35) = 3.52$ ,  $p = .001$ , Cohen's  $d = 0.54$ . Accuracy when responding to the second question (i.e., the misinformation probe in the misinformation condition) was substantially higher for the control condition ( $M = 76.81\%$ ,  $SD = 11.47\%$ ) than for the misinformation condition ( $M = 63.22\%$ ,  $SD = 16.70\%$ ),  $t(35) = 4.74$ ,  $p < .001$ , Cohen's  $d = 1.00$ . The performance level in the misinformation condition indicates that slightly over 1/3 of misinformation statements were incorrectly accepted as true, which constitutes evidence of a behavioural CIE.<sup>1</sup> There were no between-conditions differences with regards to question-2 reaction time (control

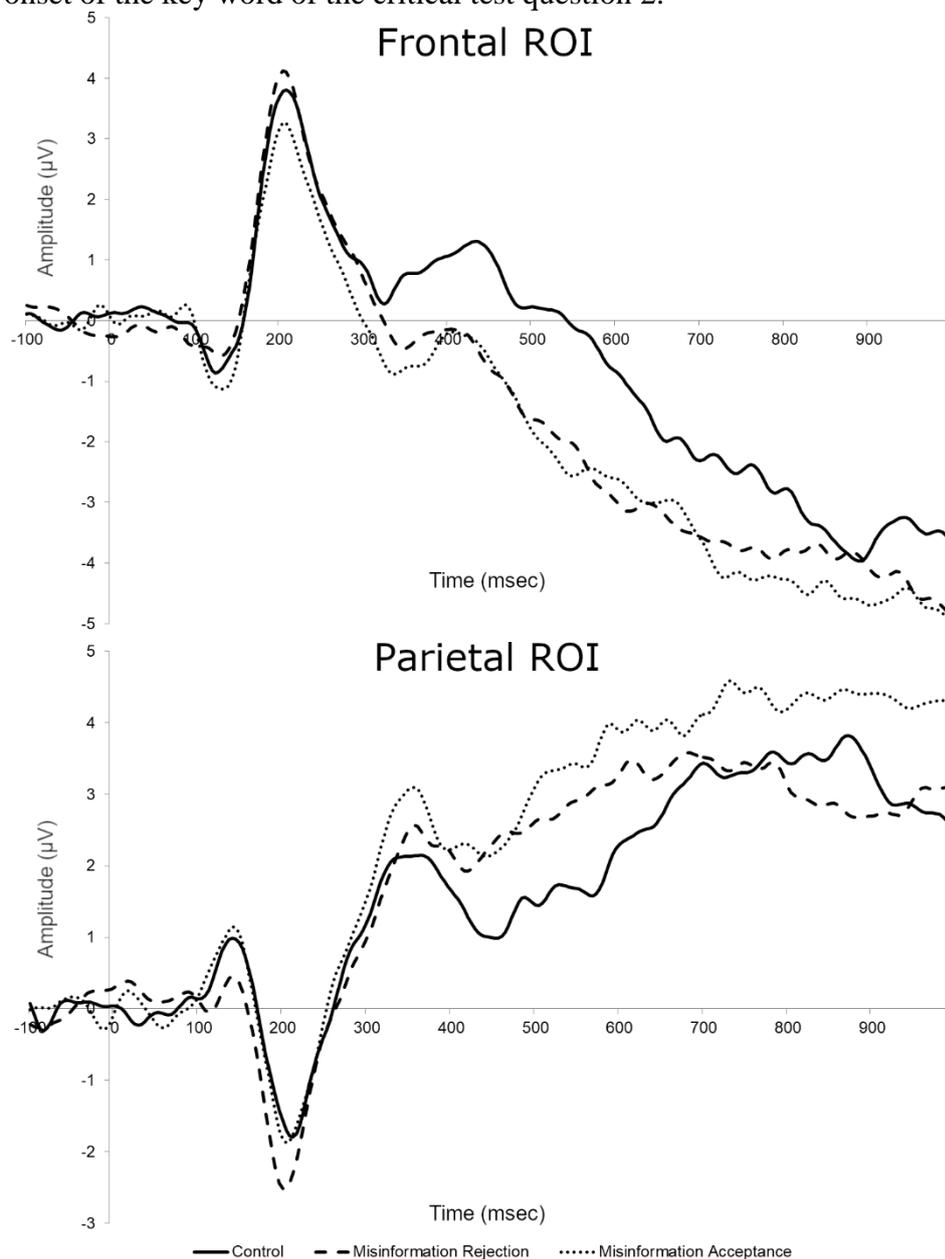
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<sup>1</sup> These results were very similar when all 47 participants were included in the behavioural analyses.

condition:  $M = 1206$  ms,  $SD = 460$  ms; rejection condition:  $M = 1170$  ms,  $SD = 483$  ms;

acceptance condition:  $M = 1336$  ms,  $SD = 494$  ms),  $F(2,70) = 3.04$ ,  $p = .054$ ,  $\eta_p^2 = .022$ .

*Figure 2.* Grand average ERP waveforms of the correctly accepted control trials (solid line), rejected misinformation (dashed line), and accepted misinformation (dotted line) at the frontal (top panel) and left-parietal ROIs (bottom panel) across conditions, time-locked to the onset of the key word of the critical test question 2.



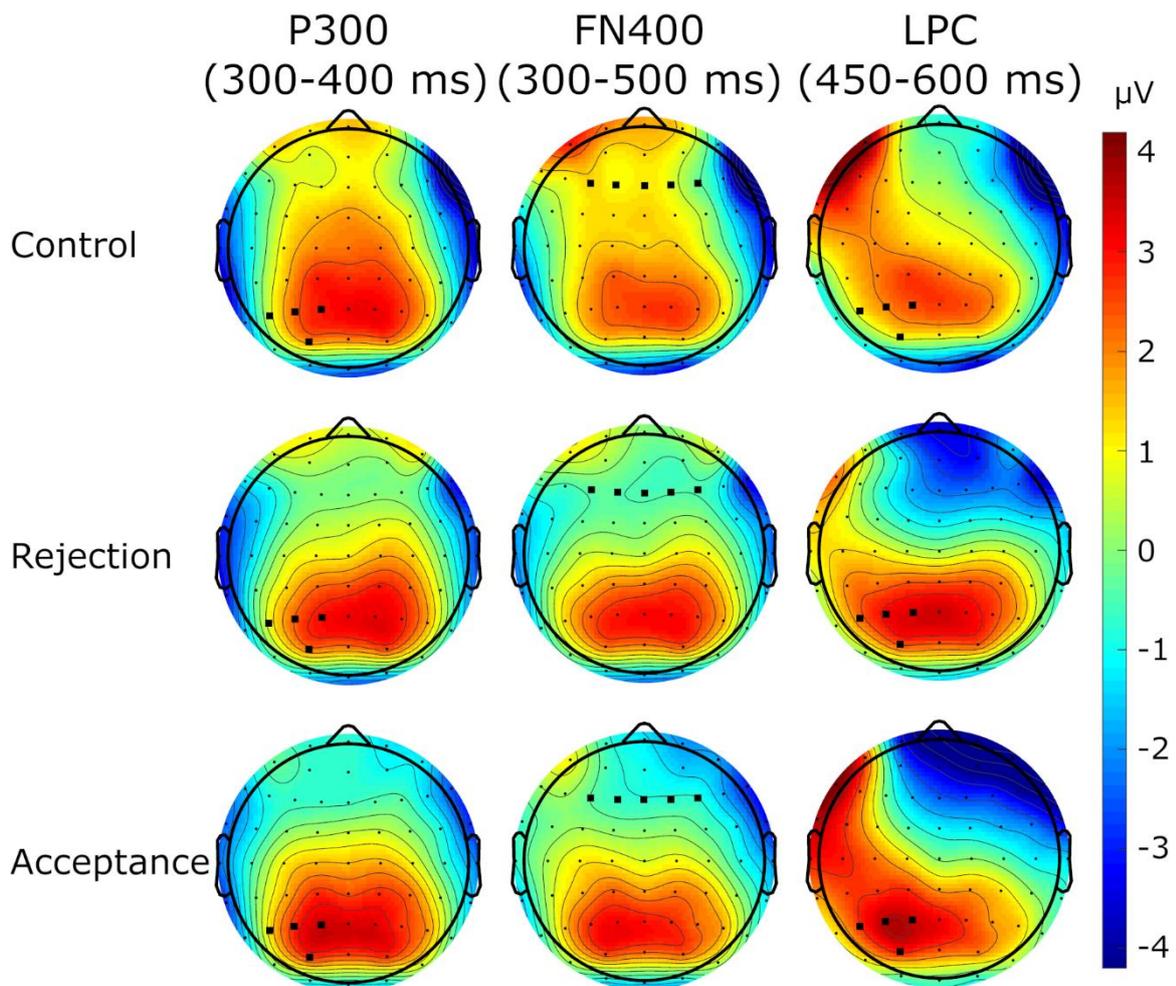
### Stimulus-Locked Electrophysiological Results

The stimulus-locked ERPs extracted from the frontal and left-parietal ROIs are presented in Figure 2, and scalp maps for each of the time windows are presented in Figure 3.

There were an average of  $M = 15.44$  epochs ( $SD = 2.26$ ) per participant in the control

condition,  $M = 30.94$  epochs ( $SD = 8.19$ ) in the rejection condition, and  $M = 18.69$  epochs ( $SD = 8.37$ ) in the acceptance condition.

Figure 3. Topographic scalp maps for each condition (top row = control condition; middle row = rejection condition; bottom row = acceptance condition) for each ERP component (left column = P300; middle column = FN400; right column = LPC). Each plot displays the mean amplitude within the time window stated for each column. Squares indicate electrodes included in the ROIs for that component.



A significant main effect of condition was observed for the FN400,  $F(2,70) = 6.17$ ,  $p = .003$ ,  $\eta_p^2 = .150$ . Planned comparisons found that the control condition ( $M = 0.79 \mu\text{V}$ ,  $SD = 3.49 \mu\text{V}$ ) was significantly more positive than the rejection condition ( $M = -0.46 \mu\text{V}$ ,  $SD = 3.41 \mu\text{V}$ ;  $t(35) = 3.15$ ,  $p = .003$ , Cohen's  $d = 0.53$ ) and the acceptance condition ( $M = -0.68 \mu\text{V}$ ,  $SD = 4.17 \mu\text{V}$ ;  $t(35) = 2.82$ ,  $p = .008$ , Cohen's  $d = 0.47$ ). The two misinformation conditions did not significantly differ from each other,  $t(35) = 0.52$ ,  $p = .609$ ,

Cohen's  $d = 0.09$ . The correlations between accuracy and amplitude for each condition were not statistically significant (control condition:  $\rho = -.10$ ,  $p = .525$ ; rejection condition:  $\rho = -.07$ ,  $p = .650$ ; acceptance condition:  $\rho = -.23$ ,  $p = .126$ ).

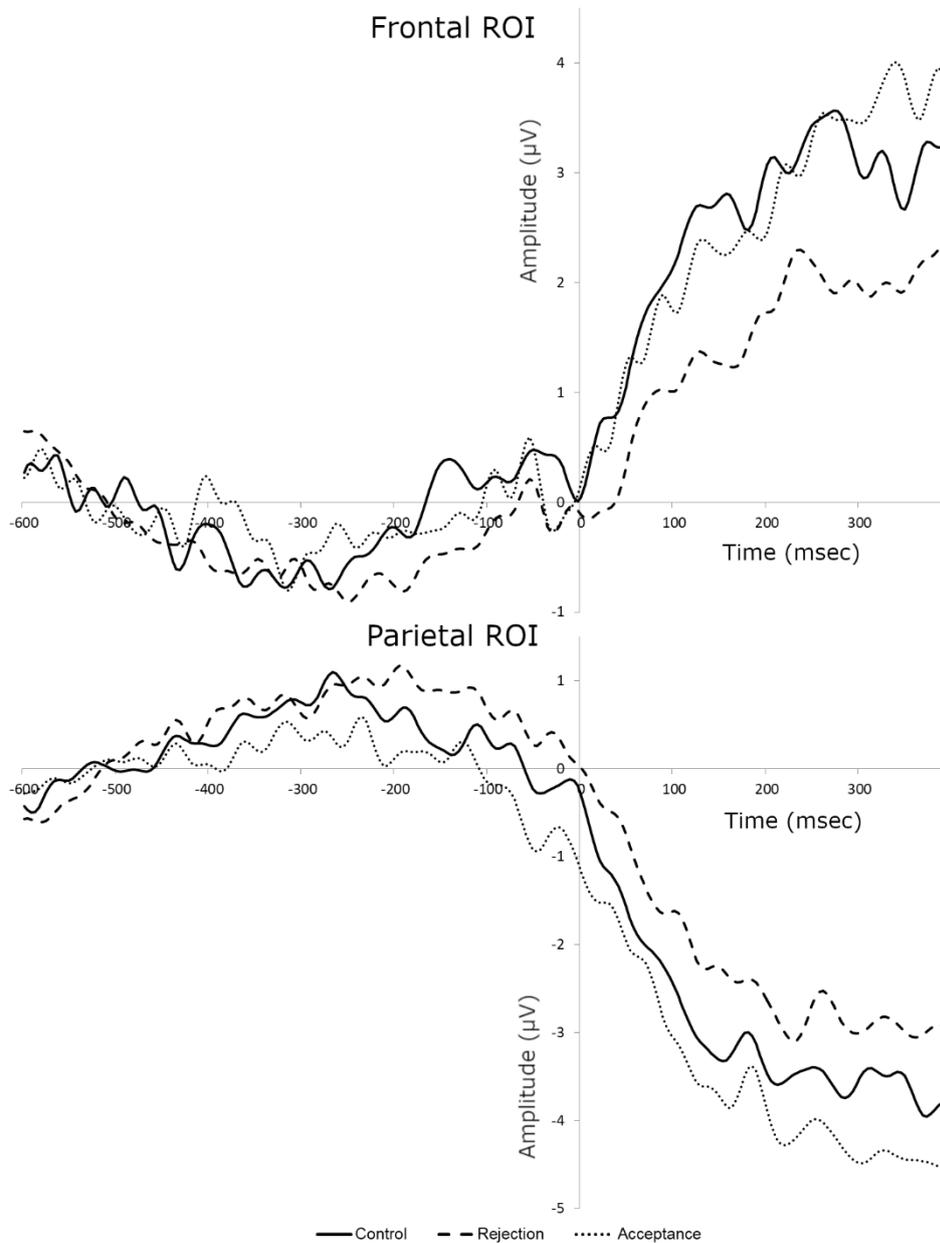
The main effect of condition was not statistically significant for the P300 component,  $F(2,70) = 1.12$ ,  $p = .331$ ,  $\eta_p^2 = .031$ . The correlations between accuracy and amplitude for each condition were not statistically significant (control condition:  $\rho = .17$ ,  $p = .273$ ; rejection condition:  $\rho = .05$ ,  $p = .751$ ; acceptance condition:  $\rho = .09$ ,  $p = .563$ ).

A significant main effect of condition was observed for the LPC component,  $F(2,70) = 3.27$ ,  $p = .044$ ,  $\eta_p^2 = .086$ . Planned comparisons found that the LPC in the control condition ( $M = 1.58 \mu\text{V}$ ,  $SD = 5.05 \mu\text{V}$ ) was significantly smaller compared to the acceptance condition ( $M = 3.17 \mu\text{V}$ ,  $SD = 6.03 \mu\text{V}$ ;  $t(35) = 2.17$ ,  $p = .037$ , Cohen's  $d = 0.36$ ). The LPC amplitude elicited by the rejection condition ( $M = 2.76 \mu\text{V}$ ,  $SD = 5.12 \mu\text{V}$ ) was numerically larger than that of the control condition, but this difference was non-significant,  $t(35) = 1.85$ ,  $p = .073$ , Cohen's  $d = 0.31$ . The two misinformation conditions did not differ from each other,  $t(35) = 0.74$ ,  $p = .464$ , Cohen's  $d = 0.12$ . The correlations between accuracy and amplitude for each condition were not statistically significant (control condition:  $\rho = .29$ ,  $p = .052$ ; rejection condition:  $\rho = .26$ ,  $p = .090$ ; acceptance condition:  $\rho = .00$ ,  $p = .987$ ).

### **Response-Locked Electrophysiological Results**

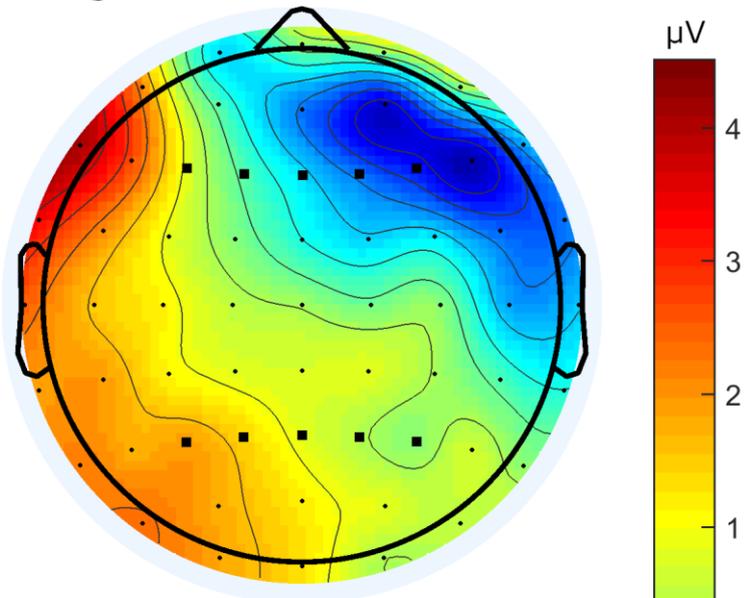
The response-locked ERPs extracted from the frontal and central-parietal ROIs are presented in Figure 4. At the frontal ROI, the rejection condition elicited a less-positive waveform than the control condition 96-172 ms post-response (20 consecutive time points). The acceptance and control conditions did not significantly differ at any point within the epoch. At the parietal ROI, the rejection and acceptance conditions did not significantly differ from the control condition for the required 12 consecutive time points. Figure 5 displays the scalp maps of the two difference waveforms.

Figure 4. Grand average ERP waveforms of the correctly accepted control trials (solid line), rejected misinformation (dashed line), and accepted misinformation (dotted line) at the frontal (top panel) and central-parietal ROIs (bottom panel) across conditions, time-locked to the response to the critical test question 2.

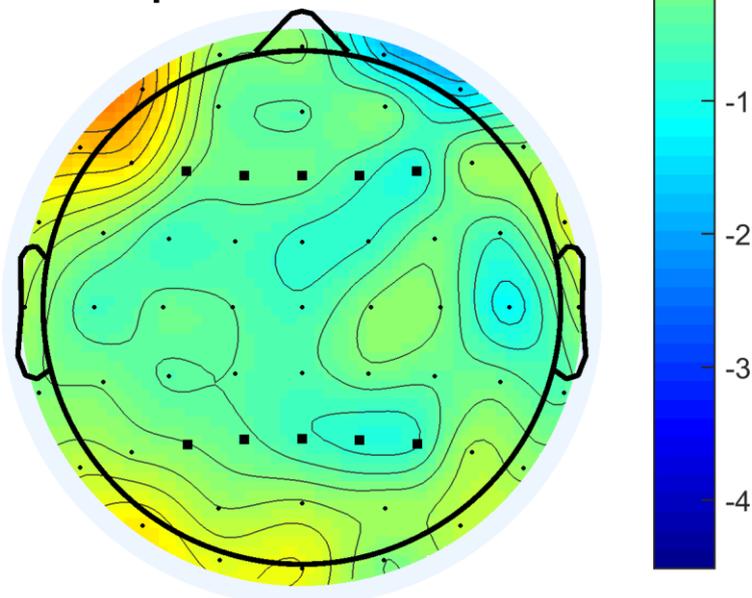


*Figure 5.* Topographic scalp maps for each difference ERP waveform (top plot: difference between rejection and control conditions; bottom plot: difference between acceptance and control conditions). Each plot displays the mean amplitude within 96-172 ms post-response. Squares indicate electrodes included in the ROIs for that component.

## Rejection - Control



## Acceptance - Control



## Discussion

The current study aimed to investigate the electrophysiological correlates of the continued influence effect of misinformation (CIE). Given previous ERP research on recognition memory and post-event misinformation effects, we hypothesised that incorrect acceptance of misinformation would elicit electrophysiological effects in frontal regions of the scalp (indicative of familiarity effects; modulation of the FN400) and left-parietal regions (indicative of context updating and recollection effects; modulation of the P300 and LPC, respectively; Stróžak, Bird et al., 2016). We observed differences between the acceptance condition and control in the FN400 and LPC components, although there were no differences between acceptance and rejection conditions. Additionally, we observed post-response differences between the rejection and control conditions in the frontal ROI.

Before discussing the effects of prime interest, we first briefly discuss the P300 findings: While parietal P300 peaks were observed in all conditions (Figure 1, at approx. 350 ms), amplitude was not significantly affected by task condition ( $\eta_p^2 = .031$ ). This is likely due to the fact that in the current task, the focus was on misinformation retrieval during inferential reasoning, rather than updating of the mental representation in memory (Donchin & Coles, 1988; Polich, 2007). As integration of the retraction into the mental event model might lead to a weakening of the misinformation representation in memory at or soon after retraction encoding (see Gordon et al., 2017; Kendeou, Walsh, Smith, & O'Brien, 2014), future research could examine whether electrophysiological differences during or immediately following the encoding of the retraction are predictive of misinformation reliance at a later testing stage. However, we note that we investigated this in two separate ERP studies that focussed on the encoding phase, neither of which observed significant

differences between rejected and accepted misinformation (see Brydges & Ecker, 2018, and Brydges, Gordon, & Ecker, 2018).

Turning to the FN400 findings, we found differences of medium effect size between the control condition and the two misinformation conditions (Cohen's  $d = 0.53$  and  $0.47$ ). Contrary to expectations (Stróžak, Bird et al., 2016), the control condition elicited a more positive amplitude than the two misinformation conditions. As alluded to in the preceding section, this finding suggests that misinformation may be rendered less familiar by a retraction, potentially as a result of the misinformation being suppressed by the integration of the retraction into the event model in memory. This could involve a process of active removal that unbinds a part representation from the mental model (Ecker, Lewandowsky, & Oberauer, 2014) or an inhibitory mechanism triggered by the co-activation of conflicting representations (Butterfuss & Kendeou, 2019). In other words, to the extent that the corrected misinformation is no longer part of the cue-activated mental event representation, the observed pattern would be expected. This finding is particularly noteworthy given the fact that the target word tended to occur repeatedly in misinformation scenarios but only once in control scenarios (compare the words “bomb” and “fire” in the examples in Table 1). The finding speaks against the theoretical notion that misinformation influences reasoning when it is automatically retrieved due to its familiarity but recollection fails (Ecker et al., 2010; Swire et al., 2017; also see Gordon et al., 2019). However, it also raises the possibility that a functionally distinct N400 component may be modulated by the repetition and associated variations in semantic processing demands (see Stróžak, Abedzadeh, & Curran, 2016). Further research is needed to determine if this is the case.

The reverse pattern was observed in the parietal LPC: accepted misinformation showed a more positive waveform than the control condition (Cohen's  $d = 0.36$ ). This is indicative of particularly strong recollection associated with the incorrect acceptance of

misinformation (Stróžak, Bird et al., 2016). This might suggest that a CIE can occur, even after successful integration of the retraction into the mental model (and thus reduced misinformation familiarity, based on the observed FN400 effects), if the test cue triggers strong recollection of the misinformation. This is in line with Ecker, Lewandowsky, Cheung, and Maybery (2015), who argued that the CIE was at least partially determined by the misinformation's availability for recollection and occurs when misinformation dominates retrieval when participants are cued during inferential reasoning tasks. However, this interpretation should be taken with caution due to the exploratory nature of the present study and the relatively weak statistical evidence. Thus, a confirmatory replication study should be conducted before drawing stronger conclusions.

An alternative interpretation might be suggested by single-process global-match models of recognition memory, which posit that FN400 amplitude modulations index overall memory strength rather than familiarity, whereas LPC effects reflect decisional factors such as decision confidence, based on findings that hits and correct rejections can elicit similar LPCs (Finnigan, Humphreys, Dennis, & Geffen, 2002) and that false alarms may also elicit an LPC-like component (Wolk et al., 2006). Curran (2004) as well as Woodruff, Hayama, and Rugg (2006) also demonstrated that decision confidence may contribute to the LPC effect. Therefore, it is possible that the more-positive LPC associated with incorrectly accepted misinformation may indicate inflated confidence rather than particularly strong recollection.

Lastly, post-response differences were observed between the rejection and control conditions, but not between the acceptance and control conditions. As no feedback was provided to participants, these differences cannot be attributed to a feedback-related negativity (Hajcak, Moser, Holroyd, & Simons, 2006). The overall effect pattern is reminiscent of a finding by Nessler and Mecklinger (2003), who reported that correct

rejections of new items in a recognition memory task elicited more-positive-going waveforms at posterior sites than correct or incorrect “old” responses in a 20-120 ms post-response time window. As this difference was larger for incorrect “old” responses, the authors discussed it as an error-related negativity, but also suggested it could reflect more generic response monitoring. In our case, such monitoring could be related to response-option valence (e.g., differential monitoring of “accept” and “reject” responses). As the frontal effect emerged primarily on the right-hand side, this appears in line with previous neuroimaging and stimulus-locked ERP research linking right-frontal activity to post-retrieval processing (e.g., Hayama, Johnson, & Rugg, 2008; Henson, Rugg, Shallice, & Dolan, 2000). However, the current study was not designed to test for post-response processing and thus did not counterbalance response-to-hand assignment, which makes it difficult to interpret the observed differences.

There are several reasons why we might not have observed pre-response ERP differences between the rejection and acceptance conditions. First, this study was largely exploratory, and thus the closest background literature (Kiat & Belli, 2017; Volz et al., 2019) used different paradigms, limiting the inferences we could draw from this research. As such, it is possible that CIE-related ERP effects occur systematically at scalp sites and/or time points that were not analysed in the present study. Even though visual inspection of the present data does not suggest such effects, future research could consider adopting a data-driven mass-univariate approach to investigating electrophysiological differences across all scalp sites and time points (e.g., Fields & Kuperberg, 2020; Groppe, Urbach, & Kutas, 2011).<sup>2</sup> The process of rejecting misinformation may also not be a reliably time-locked process. That is, the onset of the cognitive misinformation-rejection process or processes may

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<sup>2</sup> This analysis was attempted with the current sample, but no between-conditions differences were observed.

be variable, and assuming there is some electrophysiological activity associated with this process, it may have been masked by the ERP averaging process (although we note that the exploratory response-locked analyses did not support this, as differences arose only in the post-response time window). In this context, it should also be noted that some relevant retrieval processing may have occurred when the first part of the sentence was presented prior to the keyword, which thus would have been missed.

Second, given that—unlike the studies of Kiat and Belli (2017) and Volz et al. (2019)—participants in the current study were tested almost immediately after each trial, it is also possible that participants established different task sets on different trials (see Wilckens, Tremel, Wolk, & Wheeler, 2011), relying more heavily on familiarity-based processes in control trials, which featured no contradictory information and thus did not require discriminative recollection, and more recollective processing on trials involving retractions. The lack of observed differences in LPC amplitude between the accepted and rejected misinformation conditions could then mean that participants may have tried to recollect both critical sentences 2 and 4 on misinformation trials, with their response determined by the relative recollection success (i.e., weight of evidence in favour of the earlier misinformation or the more recent retraction). Such relative differences are unlikely to be differentiated in the LPC response. However, if it were indeed the case that participants established a strong task set, it would be difficult to explain the high level of incorrect misinformation acceptance, as a reliable task set based on awareness of the contradictory vs. non-contradictory nature of the scenario would have allowed participants to pre-plan the correct response. It could thus also be the case that the diminished familiarity signal associated with retracted misinformation, or

alternatively the above-mentioned keyword repetition in the misinformation scenarios, triggered the enhanced recollective processing.

Lastly, and related to the relative weighting of evidence discussed in the previous point, it is possible that the successful rejection of misinformation can be conceptualised as a diffusion process (e.g., see Ratcliff & Starns, 2009). As such, a certain level of electrophysiological activity may be required to trigger correct rejection of misinformation, but there may still be some detectable sub-threshold rejection activity on misinformation-acceptance trials; this could be mediated by the perceived credibility of the retraction (see Ecker & Antonio, 2020; O'Rear & Radvansky, 2020). As a result, ERP activity may not necessarily be dissimilar between misinformation-rejection and misinformation-acceptance conditions despite the seemingly clear-cut behavioural classification. It is also likely that participants were guessing on at least some trials, which would further obscure potential ERP effects. While our study shares this limitation with other studies (including Kiat & Belli, 2017), the relatively low number of trials across conditions made it difficult to detect potentially small condition differences. The low number of trials also contributed to the exclusion of 11 out of 47 participants, which resulted in reduced statistical power with which to detect effects.

In conclusion, misinformation elicited more negative ERP amplitudes than correctly endorsed valid information at a frontal midline ROI in a 300-500 ms time window (the FN400), and more positive amplitudes at a left-parietal ROI in a 450-600 ms time window (the LPC). We interpreted this as evidence suggesting that corrections reduce misinformation familiarity, and that continued post-retraction reliance on misinformation is associated with particularly strong misinformation recollection. Given the paucity of cognitive neuroscience research in the area of misinformation processing, a larger body of data needs to be collected before any firm conclusions can be drawn, but early findings from Kiat and Belli (2017),

Volz et al. (2019), and the current study support the idea that electrophysiological activity at midline frontal and left-parietal scalp sites is modulated by misinformation processing. We therefore hope that our study will be able to inform future research on the electrophysiology of the continued influence effect.

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