Patterns of electrical brain activation in response to socially-disputed perceptual judgments

Article *in* Neuroreport · October 2019

DOI: 10.1097/WNR.0000000000001343

4 authors:

Julie Zanesco
Université de Neuchâtel

Eda Tipura
University of Geneva

Fabrice Clément
Université de Neuchâtel

Alan J Pegna
The University of Queensland

Patterns of electrical brain activation in response to socially-disputed perceptual judgments

Julie Zanesco[a], Eda Tipura[b,c], Fabrice Clément[a] and Alan J. Pegna[d]

In recent years, neuroscience has begun to investigate brain responses to social stimuli. To date, however, the effects of social feedback on attentional and perceptual processes remain unclear. In this study, participants were asked to judge the hues of distinct, or ambiguously coloured stimuli, and to indicate their confidence ratings. Alleged social feedback was then provided, either endorsing or disputing the participants' responses. Participants were then presented the stimulus a second time and given the option to reconsider their decision. Behavioural findings showed that confidence levels decreased both with task difficulty and with conflicting social feedback. Event-related potential data showed greater P2 and N2 amplitudes for ambiguous squares compared to distinct squares upon initial stimulus presentations, compatible with heightened attention. Moreover, a decreased P300 was found for ambiguous stimuli, consistent with an increase in metacognitive activity. After social feedback, an early-late positive potential between 270 and 370 ms continued to distinguish ambiguous from distinct stimuli. More importantly, after 400 ms, the late positive potential distinguished endorsed from disputed stimuli. These results reveal that social feedback, while decreasing effects linked to uncertainty, gives rise to later processes associated with enhanced motivational significance of the stimulus following divergence from social approval.

NeuroReport 2019, **XXX:**000–000

Keywords: ambiguity, EEG-ERP, emotional expressions, late positive potential, P2, P3, perception, social conflict, social feedback, uncertainty

[a]Centre for Cognitive Sciences, University of Neuchatel, Neuchatel, [b]Faculty of Psychology and Educational Sciences, University of Geneva, Geneva, Switzerland, [c]Department of Experimental Psychology, University of Oxford, Oxford, UK and [d]School of Psychology, The University of Queensland, Brisbane, Queensland, Australia

Correspondence to Alan J. Pegna, PhD, School of Psychology, The University of Queensland, Brisbane, Queensland Qld 4072, Australia
Tel: +61733656412; fax: +61733656412; e-mail: a.pegna@uq.edu.au

Received 14 August 2019 **Accepted** 21 August 2019

Introduction

In everyday life, decisions are often made even though detailed information may be lacking. These decisions are continuously being updated by additional evidence fed back by the environment. One component contributing to decision processes that has been underestimated by cognitive neuroscience is the social information provided by individuals in our surrounding. Indeed, an individual's certainty is not only determined by the degree of ambiguity of the sensory information originating from the stimulus [1,2], but is also influenced by social cues [3], which in turn affect perceptual brain processes [4]. This latter point was suggested by Zanesco *et al.* [4] who showed that social feedback modified the early event-related potential (ERP) components in response to ambiguous stimuli already at around 100 ms. Such observations raise the question of whether later cognitive processes, indicating more controlled aspects of self-reflection, are influenced by social feedback. Indeed, conflicting and ambiguous information give rise to a subjective feeling of uncertainty [5], which in turn lead to additional allocation of attentional resources [6] and conscious control [7].

To address this question, an ERP investigation was carried out using a novel procedure (see Ref. 4 for details), in which distinct or ambiguous colour stimuli were presented to participants, who were asked to judge their colour and then rate the degree of certainty in their judgment. They were then provided with alleged social feedback that either endorsed or disputed the participants' response. The same stimuli were then shown again, and participants were given the option to maintain or revise their decision/certainty. ERPs were examined for ambiguous and distinct stimuli (initial presentations), and more importantly for endorsed and disputed ambiguous stimuli (post-feedback presentations). We reasoned that, compared to the initial stimulus presentation, ERPs for stimuli following social feedback would reveal the effects of social information on cognitive processing.

Materials and methods

Participants

Twenty paid participants (10 females; mean age = 25 ± 4) were recruited for this study (three participants were excluded due >30% errors). All were right-handed, had normal or corrected-to-normal vision and had no self-reported psychiatric or neurological disorder.

Stimuli and experimental procedure

A fixation cross was presented (400–600 ms) followed by the probe stimulus (800 ms) that was a square stimulus

0959-4965 Copyright © 2019 Wolters Kluwer Health, Inc. All rights reserved. DOI: 10.1097/WNR.0000000000001343

(5.73°) that was either of a distinct blue or green colour (16 stimuli), or of an ambiguous green/blue hue (16 stimuli controlled for isoluminance, ranging from 28.17 to 30.72 cd/m^2). After the stimulus, a response prompt (self-paced) appeared asking the participant to decide whether the stimulus was green or blue. Participants were then asked to rate their level of certainty on a scale from 1 to 5.

They were then presented with a face (1000 ms) which they were told reflected the judgement of the majority of previous participants, and which expressed either disgust (disagreement) or joy (endorsement) [8]. The stimulus sequence was then repeated in the same order, and participants were required to maintain or to revise their decision.

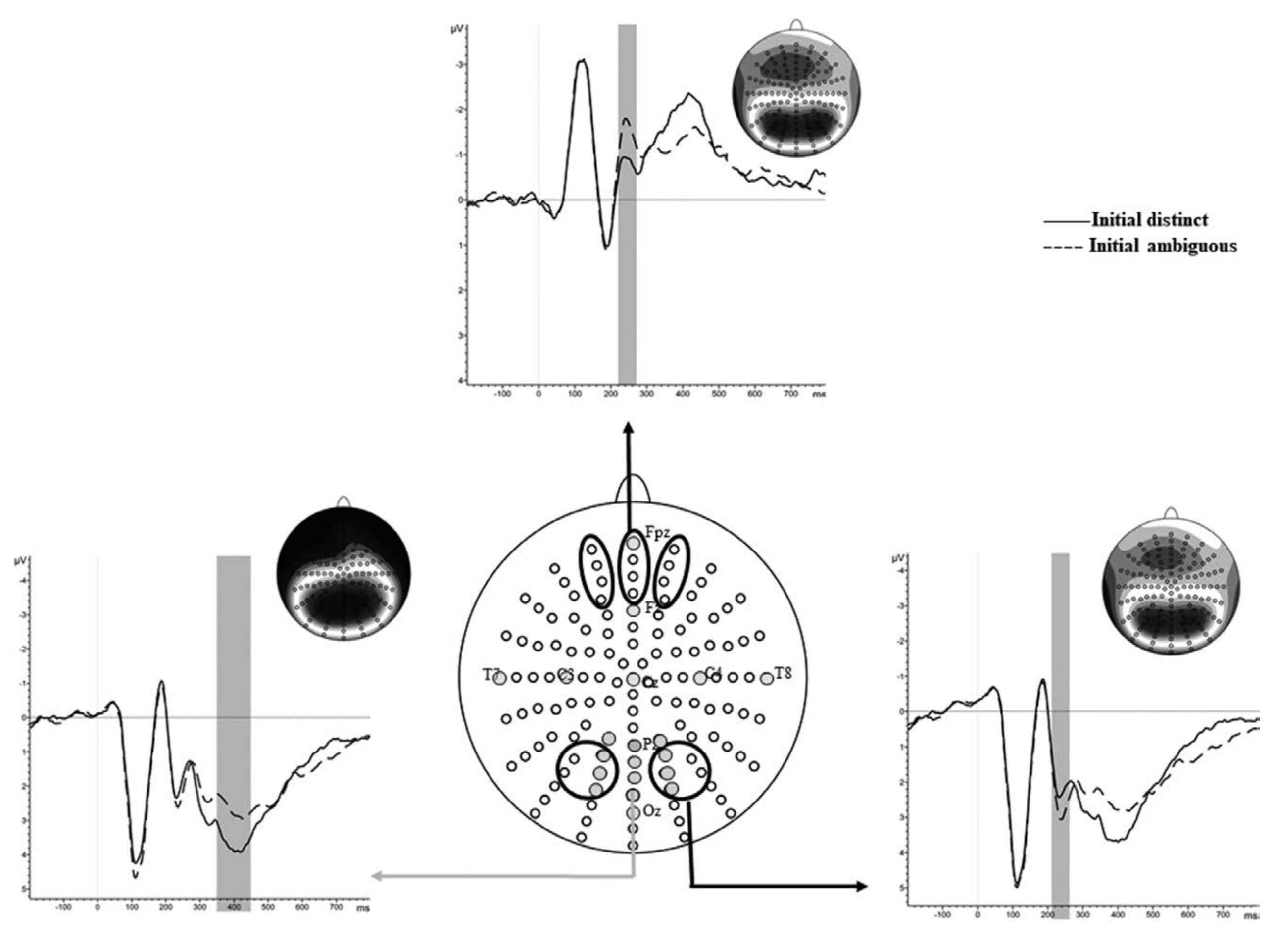
EEG acquisition

A 128-channel recording was carried out with a sampling rate of 1024 Hz using a Biosemi Active-Two system (Amsterdam, Netherlands) with AG/AgCl electrodes (electrode positions are shown in Figs. 1 and 2). Eye movements were monitored using four additional electrodes. Impedance was kept below 20 kΩ and data were referenced offline against the average reference.

EEG processing

Using Brain Vision Analyzer V.2 (Brain Products, Gilching, Germany), electro-encephalography data were downsampled to 512 Hz and filtered between 0.1 and 30 Hz. Bad electrodes were interpolated using a spherical spline (6.6% of the electrodes were interpolated). Eye movements and blinks were corrected [9], and trials containing artefacts were removed (22%). ERPs were computed for distinct and ambiguous stimuli in the initial presentation between −200 and 800 ms using the 200 ms prestimulus period for baseline correction. For the post-feedback stimulus presentations, ERPs were computed for ambiguous endorsed, ambiguous disputed and distinct endorsed conditions. In order to maintain credibility, our design did not include

Fig. 1



ERPs for ambiguous and distinct probes presented before social feedback. Pooled ERP traces are shown across electrodes used for the computation of the posterior P2 (right) and anterior N2 (top), as well as P3 (left), along with collapsed topographical voltage map illustrating the posterior P2/anterior N2 and the P3 for the two conditions of ambiguity. Central inset shows scalp viewed from above (frontal leads on top, right leads on the right), with electrodes used for P2 and N2 computation circled in black, and electrodes used for P3 computation indicated in grey.

any social dispute for distinct probes. Following visual inspection, the P2, N2 and P3 amplitudes were retained for statistical investigation of the initial presentation. For the post-feedback presentation, no P3 was observed, by contrast, a late positive potential (LPP) was found to distinguish the experimental conditions. Consequently, the P2, N2 and LPP were analysed for the post-feedback stimulus presentation. When necessary, adjusted *P* values were used to control for sphericity.

Initial stimulus presentations

Visual inspection showed differences on the P2, N2 and P3 components. The time windows for analysis were subsequently determined on the basis of the peaks and means observed in the grand averages across all conditions using a collapsed localiser. The P2 peaks (210–260 ms) were determined using a semi-automatic peak detection method and were measured over two groups of electrodes on the left and right scalp (Fig. 1). Mean amplitudes were measured for the N2 (220–270 ms) over the left, midline and right frontal electrodes (Fig. 1). P3 mean amplitudes (350–450 ms) were measured over occipito-parietal electrodes on the right, midline and left scalp (Fig. 1).

Post-feedback stimulus presentations

The same electrodes and time windows were used to compute the P2 and N2 components for the post-feedback stimulus presentations. Mean amplitudes for the LPP component were computed over a group of three occipito-temporal electrodes (Fig. 2) in two separate time windows (270–370 ms and 400–500 ms).

Results

Behavioural results

Initial presentations

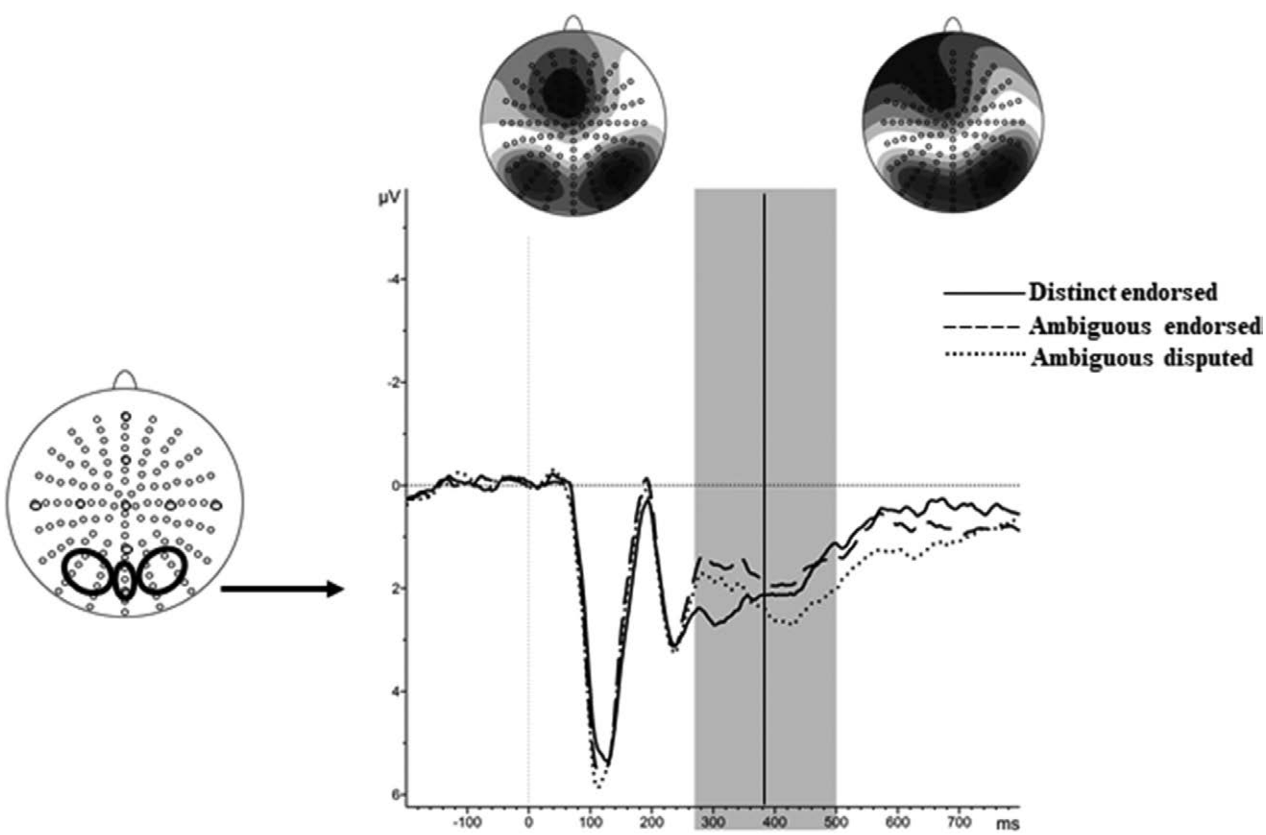
Certainty ratings for distinct stimuli were at 98.55% and at 69.87% for ambiguous stimuli.

Post-feedback presentations

For distinct (endorsed) stimuli, certainty ratings were at 99.22% while for ambiguous stimuli these were at 75.81% for endorsed and 67.07% for disputed stimuli.

An analysis of variance (ANOVA) for repeated measures was carried out on the confidence ratings of the endorsed stimuli using position (initial/second presentation) and condition (ambiguous/distinct) as factors. The main effects of position ($F(1, 16) = 21.26$, $P < 10^{-3}$) and

Fig. 2



ERPs for stimuli presented after social feedback. Traces obtained from the pooled electrodes indicated in the inset are illustrated for distinct endorsed, ambiguous endorsed and ambiguous disputed stimuli. The two periods of investigation (270–370 ms and 400–500 ms) are separated by a black line between 370 and 400 ms.

condition ($F(1, 16) = 75.3$, $P < 10^{-5}$) were significant, as well as the interaction between position and condition ($F(1, 16) = 13.3$, $P < 10^{-2}$). Post-hoc comparisons using Tukey tests revealed that the interaction was driven by a significant increase in confidence ratings between the initial and post-feedback presentations of ambiguous endorsed stimuli ($P < 10^{-3}$), effect that was not observed for distinct stimuli.

A separate two (position: initial/second presentation) × two (type of feedback: endorsed/disputed) ANOVA was performed on the confidence ratings for ambiguous stimuli alone, examining confidence rating before and after endorsement and dispute. This analysis revealed significant main effects of position ($F(1, 16) = 5.75$, $P < 10^{-1}$) and type of feedback ($F(1, 16) = 12.3$, $P < 10^{-2}$), with endorsement leading to higher confidence ratings than dispute. A significant interaction was also found between position and type of feedback ($F(1, 16) = 12.3$, $P < 10^{-2}$), which was due to the fact that confidence ratings rose significantly after endorsement compared to the initial rating (Tukey post-hoc; $P < 10^{-1}$), but decreased after dispute ($P < 10^{-3}$).

Results of the self-report questionnaire revealed that 64.7% of the participants always believed in the social cue, 17.65% stated that they believed in it occasionally and 17.65% (three subjects) reported that they did not. Participants reporting disbelief in feedback authenticity nevertheless showed confidence ratings of 71% for ambiguous probes following social endorsement, compared to 68.4% before social feedback. Their mean confidence level following disagreement was 69.3%. The differences in the sceptical group, reveal that they were influenced by the valence of the cue in spite of their apparent disbelief.

Electrophysiological results

Initial stimulus presentation

Posterior P2 amplitude The ANOVA showed a significant main effect of ambiguity ($F(1,16) = 8.08$, $P < 0.10^{-1}$). The P2 peak was significantly greater for the initial ambiguous probes (3.8 ± 2.78 μV), compared to the distinct ones (3.2 ± 2.73 μV) (Fig. 1, right).

Anterior N2 amplitude The ANOVA revealed a main effect of ambiguity ($F(1, 16) = 9.52$, $P < 0.10^{-2}$). The N2 mean amplitudes were significantly more negative for the presentation of initial ambiguous probes (−1.52 ± 2.36 μV) compared to the presentation of initial distinct probes (−0.83 ± 2.65 μV) prior social feedback (Fig. 1, top).

P3 amplitude The ANOVA showed a main effect of ambiguity ($F(1, 16) = 12.21$, $P < 0.10^{-2}$). The P3 mean amplitude was significantly larger for the presentation of initial distinct probes (3.7 ± 2.5 μV) than for the presentation of initial ambiguous probes (2.7 ± 2.2 μV) before social feedback (Fig. 1, left).

Second (post-feedback) stimulus presentation

Posterior P2 amplitude The ANOVA performed on P2 mean amplitudes after feedback probes revealed no significant differences between the three conditions ($F(1.41, 22.6) = 0.5$, adj. $P > 0.05$) (distinct endorsed = 4.05 ± 2.04 μV, ambiguous endorsed = 4.00 ± 1.9 μV, ambiguous disputed = 4.21 ± 2.04 μV).

Anterior N2 amplitude The same repeated measures ANOVA for post-feedback probes did not reveal any significant effect of social feedback ($F(1.74, 28) = 0.5$, $P > 0.05$). There were no significant differences between the presentation of post-endorsed distinct probes (−2.4 ± 1.9 μV), post-endorsed ambiguous probes (−2.1 ± 1.44 μV) and post-disputed ambiguous probes (−2.2 ± 1.22 μV). Only a main effect of laterality was observed ($F(2, 32) = 7.64$, $P < 10^{-2}$).

Late positive potential The ANOVA carried for the 270–370 ms window revealed main effects of condition ($F(1.89, 29.5) = 9.4$, $P < 10^{-3}$) and laterality ($F(1.81, 28.9) = 7.8$, $P < 10^{-2}$). Post-hoc comparisons using Tukey tests showed that the early posterior positivity mean amplitude was significantly larger for distinct endorsed probes (2.3 ± 1.9 μV), compared to both ambiguous conditions (ambiguous endorsed = 1.4 ± 1.7 μV, $P < 10^{-4}$; ambiguous disputed = 1.8 ± 1.6 μV, $P < 10^{-4}$). The mean amplitudes were significantly larger over the right and left hemisphere leads (right: 2.4 ± 1.7 μV; left: 2.03 ± 1.9 μV) compared to the midline ones (1.08 ± 1.7 μV).

The ANOVA for the later LPP window (400–500 ms), showed a main effect of condition ($F(1.32, 21.05) = 4.6$, $P < 10^{-1}$), with post-hoc Tukey tests showing that mean amplitudes were significantly greater for ambiguous disputed probes (2.38 ± 1.5 μV) than the two endorsed conditions, while these latter two did not differ significantly (distinct endorsed: 1.71 ± 1.5 μV; $P < 10^{-1}$; ambiguous endorsed: 1.65 ± 1.5 μV; $P < 10^{-1}$) (Fig. 2).

Discussion

The behavioural results in this study showed that participants believed in the authenticity of the social feedback and modified their responses accordingly.

The ERPs obtained for the initial presentation of the ambiguous stimuli showed an enhanced posterior P2/anterior N2 amplitude starting at around 200 ms. These increases in P2/N2 amplitudes are in line with other findings in the literature that have demonstrated similar responses under conditions of uncertainty [10,11]. The P3 component was greater for distinct stimuli. The P3 has been interpreted as reflecting different functions. One suggestion is that it represents attentional engagement [12]. Indeed, it has been noted that under more demanding task conditions, the P3 amplitude is decreased, contrary to less demanding situations [13,14]. In our investigation, the increased difficulty for ambiguous stimuli may have necessitated greater attentional engagement leading to a decreased P3 component. Alternatively, a more recent interpretation has been advanced, suggesting that the P3 may be a marker of neural activity which could be linked to metacognition. The term metacognition denotes the explicit representations an agent has of their cognitive processes and can be more broadly defined as cognition about cognition [15]. This self-reflective ability is thought to increase in the face of uncertainty. Recent investigations have examined the relation between the P3 and the participants' certainty with regards to the stimulus [16]. Using target detection tasks, it has been observed that as sensory evidence builds up with increasing evidence, participants' accuracy increases, and the P3 builds up more rapidly, peaking earlier and with a greater amplitude [17–19]. This has led to the suggestion that the P3 may act as a 'decision variable' reflecting the accumulation of sensory information that culminates with the participant' decision [17]. This finding could also account for our observations, in which more distinct colours would have led to a rapid build-up of sensory evidence allowing an unequivocal response, which was lacking for ambiguous colours.

Although P2/N2 and P3 differences were found before feedback, the ERPs observed after social feedback differed quite clearly. Indeed, the enhanced P2/N2 responses for ambiguous stimuli were no longer observed, and no P3 topography was found. This appears to suggest that when viewing the stimulus a second time, the subsequent attentional engagement (or build-up of sensory information) did not occur. Instead, an LPP after approximately 350 ms differentiated disputed and endorsed stimuli.

Different interpretations could be advanced for this LPP. Firstly, it could be speculated that social feedback modulated the emotional value of the stimulus. Indeed, emotionally-valenced stimuli have been found to activate a similar late component. Ito *et al.* [20] reported a late centro-parietal positivity for emotional stimuli that was more marked for negative images, when these were set in a context of neutral images. The finding was replicated by Huang and Luo [21] for negative images in a valence judgment task. Others have reported a similar component for both positively and negatively-valenced stimuli [22–25]. In this context, the LPP may be an indication of an emotional appraisal of the stimuli due to their 'incorrect' classification by the participant. Alternately, their emotional value may have led to changes in attentional engagement.

Within the current context, it might therefore be argued that social disagreement enhances stimulus reprocessing due to what we would term a social epistemic discrepancy, created by the divergence between the participants' judgment and the dominating social opinion. This appears to modify the emotional value of the stimulus and to bring about later processes causing the ambiguous stimulus to gain a different emotional value.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

References

1 Selimbeyoglu A, Keskin-Ergen Y, Demiralp T. What if you are not sure? Electroencephalographic correlates of subjective confidence level about a decision. *Clin Neurophysiol* 2012; **123**:1158–1167.

2 Yeung N, Summerfield C. Metacognition in human decision-making: confidence and error monitoring. *Philos Trans R Soc Lond B Biol Sci* 2012; **367**:1310–1321.

3 Eskenazi T, Montalan B, Jacquot A, Proust J, Grèzes J, Conty L. Social influence on metacognitive evaluations: the power of nonverbal cues. *Q J Exp Psychol (Hove)* 2016; **69**:2233–2247.

4 Zanesco J, Tipura E, Posada A, Clément F, Pegna AJ. Seeing is believing: early perceptual brain processes are modified by social feedback. *Soc Neurosci* 2019; **14**:519–529.

5 Smithson M. Probability judgments under ambiguity and conflict. *Front Psychol* 2015; **6**:674.

6 Dieterich R, Endrass T, Kathmann N. Uncertainty is associated with increased selective attention and sustained stimulus processing. *Cogn Affect Behav Neurosci* 2016; **16**:447–456.

7 Shimamura AP. Toward a cognitive neuroscience of metacognition. *Conscious Cogn* 2000; **9**:313–323; discussion 324.

8 Langner O, Dotsch R, Bijlstra G, Wigboldus DH, Hawk ST, Van Knippenberg AD. Presentation and validation of the Radboud faces database. *Cogn Emot* 2010; **24**:1377–1388.

9 Gratton G, Coles MG, Donchin E. A new method for off-line removal of ocular artifact. *Electroencephalogr Clin Neurophysiol* 1983; **55**:468–484.

10 Gole M, Schäfer A, Schienle A. Event-related potentials during exposure to aversion and its anticipation: the moderating effect of intolerance of uncertainty. *Neurosci Lett* 2012; **507**:112–117.

11 Wang L, Sun H, Li L, Meng L. Hey, what is your choice? Uncertainty and inconsistency enhance subjective anticipation of upcoming information in a social context. *Exp Brain Res* 2018; **236**:2797–2810.

12 Polich J. Updating P300: an integrative theory of P3A and p3b. *Clin Neurophysiol* 2007; **118**:2128–2148.

13 Kok A. On the utility of P3 amplitude as a measure of processing capacity. *Psychophysiology* 2001; **38**:557–577.

14 Olofsson JK, Polich J. Affective visual event-related potentials: arousal, repetition, and time-on-task. *Biol Psychol* 2007; **75**:101–108.

15 Shea N, Boldt A, Bang D, Yeung N, Heyes C, Frith CD. Supra-personal cognitive control and metacognition. *Trends Cogn Sci* 2014; **18**:186–193.

16 Desender K, Van Opstal F, Hughes G, Van den Bussche E. The temporal dynamics of metacognition: dissociating task-related activity from later metacognitive processes. *Neuropsychologia* 2016; **82**:54–64.

17 Kelly SP, O'Connell RG. Internal and external influences on the rate of sensory evidence accumulation in the human brain. *J Neurosci* 2013; **33**:19434–19441.

18 Murphy PR, Robertson IH, Harty S, O'Connell RG. Neural evidence accumulation persists after choice to inform metacognitive judgments. *Elife* 2015; **4**:e11946.

19 Twomey DM, Murphy PR, Kelly SP, O'Connell RG. The classic P300 encodes a build-to-threshold decision variable. *Eur J Neurosci* 2015; **42**:1636–1643.

20 Ito TA, Larsen JT, Smith NK, Cacioppo JT. Negative information weighs more heavily on the brain: the negativity bias in evaluative categorizations. *J Pers Soc Psychol* 1998; **75**:887–900.

21 Huang YX, Luo YJ. Temporal course of emotional negativity bias: an ERP study. *Neurosci Lett* 2006; **398**:91–96.

22 Hajcak G, MacNamara A, Olvet DM. Event-related potentials, emotion, and emotion regulation: an integrative review. *Dev Neuropsychol* 2010; **35**:129–155.

23 Cuthbert BN, Schupp HT, Bradley MM, Birbaumer N, Lang PJ. Brain potentials in affective picture processing: covariation with autonomic arousal and affective report. *Biol Psychol* 2000; **52**:95–111.

24 Schupp HT, Cuthbert BN, Bradley MM, Cacioppo JT, Ito T, Lang PJ. Affective picture processing: the late positive potential is modulated by motivational relevance. *Psychophysiology* 2000; **37**:257–261.

25 Dolcos F, Cabeza R. Event-related potentials of emotional memory: encoding pleasant, unpleasant, and neutral pictures. *Cogn Affect Behav Neurosci* 2002; **2**:252–263.