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Jennifer T Coull, Julien Cotti, Franck Vidal. Increasing activity in Left Inferior Parietal Cortex and right Prefrontal Cortex with increasing temporal predictability: An fMRI study of the hazard function. International conference on timing and time perception, Time In MEntaL activitY: theoretical, behavioral, bioimaging, and clinical perspectives (TIMELY) network, Mar 2014, Corfou, Greece. pp.41-44, 10.1016/j.sbspro.2014.02.311 . hal-01384050

HAL Id: hal-01384050

<https://hal.science/hal-01384050>

Submitted on 25 Feb 2019

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ICTTP 2014

Increasing activity in Left Inferior Parietal Cortex and right Prefrontal Cortex with increasing temporal predictability: An fMRI study of the hazard function

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Abstract

The longer we wait for an event to occur, the higher the probability that it will soon arrive (the “hazard function”). Confirming previous findings, we found that RTs decreased across the foreperiod when target onset was unpredictable/variable but remained constant when it was predictable/fixed. Left inferior parietal cortex was activated not only by fixed prior temporal predictions but also as a function of the evolving temporal predictability across the foreperiod. By contrast, right prefrontal cortex was activated by evolving, but not by fixed, temporal predictions. Importantly, brain activity associated with evolving predictability was independent from that underpinning perception of the foreperiod duration itself.

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Selection and peer-review under responsibility of the Organizing Committee of the International Conference on Timing and Time Perception.

Keywords: Prediction; Expectation; Probability; Prior; Likelihood; Preparation; Anticipation

1. Introduction

Knowing an event will occur at a particular moment in time generates temporal predictions that facilitate stimulus processing. Left inferior parietal cortex (IPC) mediates this process, whether the prediction is being used to enhance motor speed (Coull & Nobre, 1998; Cotti, Rohenkohl, Stokes, Nobre & Coull, 2011) or perceptual discrimination (Davranche, Nazarian, Vidal & Coull, 2011), whether it is generated from visual (e.g., Coull & Nobre, 1998) or auditory (Bolger, Coull, & Schön, in press) sources, or even whether it is triggered endogenously

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by learned sensory cues (e.g., Coull & Nobre, 1998) or exogenously by the temporal (e.g., rhythmic) structure of the event itself (Bolger et al., in press; Marchant & Driver, 2013).

Even when there is no sensory input to generate temporal predictions, the forward flow of time itself can be used to generate and update predictions dynamically. As time elapses, the increasing conditional probability that an event will occur given that it has not already occurred (the “hazard function”) leads to an ever-heightening sense of temporal certainty. Empirically, the longer we wait for an event to occur, the more certain we are of its occurrence, and so the faster we are to respond to it (Niemi & Näätänen, 1981).

The dynamic evolution of temporal predictability engages right prefrontal cortex (PFC; Coull, Frith, Büchel, & Nobre, 2000; Vallesi, McIntosh, Shallice, & Stuss, 2009), primary visual cortex and Supplementary Motor Area (SMA; Bueti, Bahrami, Walsh, & Rees, 2010). In the current study, we refine these findings by comparing the neural substrates of dynamically changing predictions to those of fixed prior predictions within a single experimental paradigm. In so doing, we aim to identify areas whose activity increases as a function of increasing temporal predictability whilst controlling for the neural substrates of the elapse of time itself.

2. Methods

Sixteen right-handed volunteers performed a cued visual reaction time (RT) task with variable foreperiods (FP) (Figure 1). In the temporal condition, participants could use the cue to predict FP duration and so improve RTs. In the neutral condition, participants could not predict FP duration in advance.

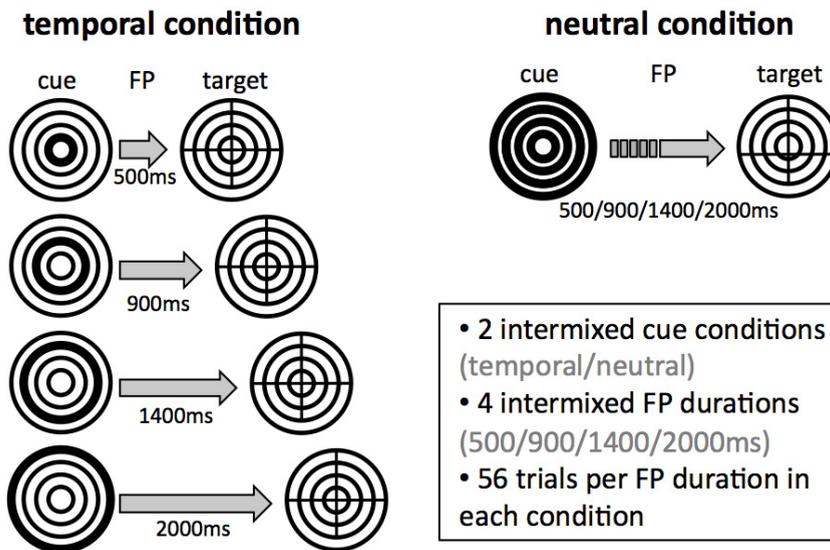


Fig. 1. Cued visual RT task.

3. Results

3.1. Behavioural data

There were highly significant main effects of both experimental condition and FP, and a significant interaction [$F(3,45)=93.64$, $p<0.0001$] between the two (Figure 2). These data suggest temporal predictability remained constant across FP in the temporal condition, but increased as a function of FP in the neutral condition (the hazard function).

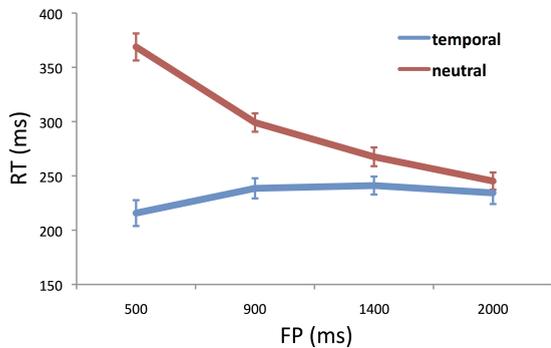


Figure 2: RTs for temporal and neutral conditions as a function of FP.

3.2. fMRI data

fMRI images (30x4mm transverse slices; TR=2s.) were pre-processed and analysed with SPM8 (<http://www.fil.ion.ucl.ac.uk/spm/software/spm8>). The main effect of experimental condition (temporal vs. neutral) confirmed prior reports that left IPC is significantly more activated by temporal, than neutral, cueing. The main effect of FP (parametrically increasing FP) showed that activity in SMA, premotor cortex and primary visual cortex increased with increasing FP. The interaction between condition and FP revealed that activity in left IPC and right PFC increased as a function of FP more in the neutral condition than in the temporal condition (Figure 3).

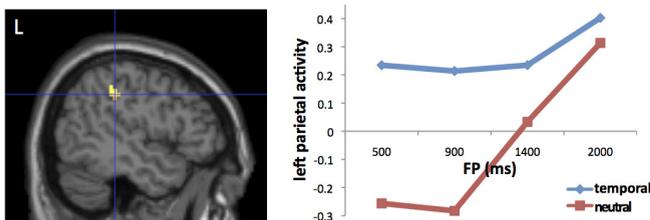


Figure 3: Left IPC activity increases with FP more in the neutral, than the temporal, condition.

4. Discussion

Knowing in advance when a target is likely to appear (temporal condition) activates left IPC independently of FP duration. When no advance temporal information is provided (neutral condition), both left IPC and right PFC become steadily more activated as temporal predictability increases with FP duration (the hazard function). These data confirm previous findings that left IPC plays a key role in the behavioural benefits of temporal predictions, and extends these findings by showing that it is activated even when temporal predictions are generated and updated by the flow of time itself.

Acknowledgements

We thank Bruno Nazarian for help with stimulus development. This work was funded by ECRP-SS and ANR grants awarded to JTC.

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