**Research proposal:  
Breakthrough Percepts of Faces of Varying Saliences: A Fringe-P3 analysis  
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The central objective of all psychological research is to establish the processes, structures and phenomena that define the mind, by measuring what can be physically observed. This challenge is especially apparent in the field of neurocognition, wherein an understanding of unseen intellectual mechanisms is pursued through the examination of the physiological behaviour of the brain. The study of attention, and the factors that contribute to its allocation, is no exception to this. In order to address this challenge in the investigation of how we attend to stimuli in our environment, a range of methods have been developed.

One such technique is the Rapid Serial Visual Presentation (RSVP) paradigm (Potter, 1976). In this task, participants view sequences of visual stimuli, presented in rapid succession, often while performing other cognitive tasks – such as the identification of certain target stimuli from the given stream of images. By manipulating elements of the procedure, such as the stimuli or task given to participants, this method has been used to uncover important insights into the nature of cognition and attentional processing, such as the limits of attentional capacity and the process by which attention is selectively directed. In particular, a study from Shapiro et al. (1997) demonstrated that the allocation of attention to target stimuli, presented via RSVP, was influenced by the personal salience attributed to the stimuli viewed. Similarly, in a subsequent paper from Shapiro et al. (1999), attention was recognised to be enhanced towards stimuli made salient by their affective connotations, such as those associated with aversive words.

Evidently, the RSVP paradigm serves as a valuable tool for the measurement of latent mental processes, and has highlighted the role of salience as pertinent in the allocation of attention to visual stimuli. In addition to the use of this behavioural measure in isolation, however, there has been an increasing number of recent studies implementing the RSVP paradigm in combination with neuroimaging methods. In one such study, by Alsufyani et al. (2017), electroencephalography (EEG) was used to record the neural electrophysiological responses of participants’ brains while they viewed sequences comprising images of different faces, presented via RSVP. From their investigation, they observed a pattern of neural signalling that consistently occurred in response to the presentation of faces that were salient. Specifically, they reported the P300 event-related potential (ERP) waveform as a reliable neural signature for the detection of salient face stimuli. This finding was further replicated in a subsequent paper from Alsufyani et al. (2021), wherein the researchers identified the same electrophysiological signal in response to the presentation of (salient) famous names, through a similar EEG-RSVP methodology (referred to as the ‘Fringe-P3 technique).

These reports introduce this Fringe-P3 technique as a potentially revolutionary new approach to the examination of latent mental processes. Specifically, the evident effectiveness of this technology in the identification of perceived salience from a sample’s measured neural activity, without the requisite of subjects explicitly disclosing this cognitive experience, demonstrates its particular relevance to the elusive topics of mind-reading and deception-detection. Furthermore, empirical studies testing the practical application of this tool have successfully demonstrated its functional utility for real-world objectives, such as use in forensic services. In a key study from Bowman et al. (2013), for example, the Fringe-P3 methodology was implemented and observed to reliably detect deceptive disclosures of identity from individual participants. In a similar investigation by Harris et al. (2021), the technique was used in the context of a concealed knowledge test, in which participants attempted to conceal their familiarity towards their own email addresses, as it was presented among RSVP streams of other stimuli. Through the detection of the P300 response, the salient email addresses of participants were identified – linking their online and real-world identities without any explicit disclosure of this connection. These findings therefore illustrate key evidence for the appropriate and effective use of this technology in real-world use-cases, such as cybercrime investigations.

While the aforementioned literature evidently offers a consistent demonstration of the role of the P300 signal in the neurocognitive processing of salient stimuli, as well as the utility of the tool used to detect this phenomenon in real-life practical objectives, there remains much value in further exploration of this topic. Specifically, while empirical investigations thus far have focused on identifying the P300 from RSVP-presented salient and non-salient stimuli, there has been limited exploration of how different forms of salience may affect this response. Specifically, whether the extent to which the given probes are salient, or the type of salience attributed to these given stimuli, influence the electrophysiological response recorded from the brain. Furthermore, while some studies have indicated the capacity at which this P300 salience signal can be identified from individual participant data, the majority of research relating to this topic has constituted analyses of effects from group-level data.

In the proposed study, therefore, we aim to contribute to the existing base of empirical literature surrounding the P300 salience response and the practical application of this Fringe-P3 method in scenarios with relevance to real-life. We aim to achieve this using data collected as part of an uncompleted PhD project by Aviles and Bowman (2019), in which participants were tasked with identifying different types of salient target faces, presented at different strengths of salience, from RSVP streams of sequentially-presented face stimuli. Specifically, by comparing responses to the experiment’s manipulations of the target probes as either inherently salient (on the basis of the face’s fame and universal recognisability), incidentally salient (on the basis of the face’s spontaneous relevance and relevance in the experiment) or non-salient, our analysis will examine how neural activations occur in response to probes of these different types of salience. Additionally, by comparing responses to the experiment’s manipulations of each target at different salience strengths, with the responses to the non-salient stimuli, our analysis will examine how neural activations occur in response to probes of different extents of salience. These comparisons will also be performed at the group-level (across the entire sample data) and at the individual-level (within each participant’s data), to examine whether the same information, regarding the salience of the presented face stimuli, can be discerned from the electrophysiological recording of individual participants, as well as from the neural signals measured across the entire group. On the basis of the aforementioned existing literature, we hypothesise that we will establish a differential pattern of responding between conditions of salience type. Specifically, we expect to find stronger responses to stimuli of inherent salience than to stimuli of incidental salience, and stronger responses to stimuli of incidental salience than to stimuli of no salience. We also hypothesise that differential responses will be found for stimuli of different salience strengths, with those of stronger salience eliciting a stronger response. Specifically, we expect that the response will be low for stimuli below a given salience threshold, increasing quickly once the salience reaches a level at which the target probe appears distinct along this dimension, to participants.

**Method**

**Design**

Aviles and Bowman’s (2019) experiment recruited a within-subjects design, comprising four blocks of testing: one practice block of 10 RSVP streams and three experimental blocks each containing 120 streams. Each stream tasked participants with detecting a given target among a sequence of 18 faces.

Each block used a different target. The target for the practice streams constituted the face of a random non-famous male. The targets for the first and second experimental blocks, respectively, constituted the faces of former US president Donald Trump and Duchess of Sussex Meghan Markle. These faces were assumed to be inherently salient due to their worldwide fame and recognisability. The target for the final experimental block constituted the non-famous male face from the practice streams, assumed to have attained incidental salience as a result of these previous presentations.

The faces of each stream included 17 distractors (random non-salient faces, to be ignored) and one critical probe. In half of the streams of each block, the critical probe constituted either a face of a certain likeness to the initially-presented salient target (target probe; target-present condition) or a face of a certain likeness to a non-salient control (control probe; target-absent condition). The order of the target-present and target-absent trials in every set of 12 streams was randomised, to control for any possible confounding order effects that might result from condition trials occurring together. The critical probes used for each set of 12 streams within each block were kept equal in likeness to their respective target and control faces. Thus, blocks began with probes of 10% likeness, incrementally increasing by 10% every 12 streams until the probes of the final 12 streams were of 100% likeness to their respective target/control faces. The critical probe of each stream was pseudorandomly positioned between the second and eleventh distractors, to ensure that it could be identified in an unanticipated and natural way.

The dependent variable of this experiment was therefore the amplitudes of the ERPs recorded from participants. The three independent variables were the manipulations of the target probes, operationalised as salience (target-presence/target-absence), type of salience (inherently-salient male/inherently-salient female/incidentally-salient male), and strength of salience (decile levels of likeness between the target probe and target). This design permits the comparison between responses to faces of different salience types, at each salience strength, and responses to faces of no salience. Our proposed analysis will retain this design, using cluster-based two-sample permutation tests to make these comparisons.

**Participants**

Fourteen students from the University of Kent were recruited to participate in the experiment. All participants were self-selecting, had normal or corrected-to-normal vision, and were recruited opportunistically in two batches. The first batch of seven participants underwent testing between September and December 2018. The second batch of seven more participants underwent testing in June 2019. Informed consent was obtained from each participant prior to recruitment, and participants were each compensated £20 for taking part. Data from all participants will be utilised for the purposes of the proposed analysis.

**Materials**

***Apparatus***

Aviles and Bowman’s experiment took place at the School of Computing EEG lab, at the University of Kent. The RSVP streams were generated using MATLAB version 19.13.0 R2022b (The MathWorks Inc., 2022) and displayed on a 20” LCD screen with a refresh rate of 60Hz and a 1600×1200 pixel resolution. A BioSemi ActiveTwo system (BioSemi BV, Amsterdam, The Netherlands) was used to collect the EEG data from 32 electrode sites, while participants viewed the RSVP streams.

The FieldTrip toolbox for MATLAB (Oostenveld et al., 2011) will be used to pre-process and analyse the collected EEG data.

***Stimuli***

All face stimuli constituted forward-facing, monochrome images of males and females, sized at 640×480 pixels. The non-famous male target face was randomly selected from Minear and Park’s (2004) face database. 560 non-salient faces were also obtained from Minear and Park’s database, for use as distractors. The critical probe of each stream constituted either a likeness variant of the initially-presented target (representing the given target at different strengths of salience) or a likeness variant of a non-salient control face, generated by taking each target or control and superimposing it over one of the random, non-salient faces at ten levels of opacity (decile percentage increases, from 10% to 100%), to produce four sets of 10 images, each varying in likeness to the face from which they were developed.

**Procedure**

Participants undertook the experiment individually, in a quiet room. After providing their informed consent, participants sat 60cm from a monitor, ready for the experiment. The experiment involved an initial practice block of 10 streams, followed by three experimental blocks each containing 120 streams. The target faces for each block were presented to participants at the start of the experiment. Each stream began with the display of a central fixation cross for 500ms, followed by the sequence of 18 faces, with each face presented for 133ms. For the practice block, participants searched for a non-famous male face target. For the subsequent experimental blocks, the targets constituted the faces of Donald Trump, Meghan Markle, and the non-famous male face from the practice trials, respectively. Each stream comprised 17 non-salient distractors and one critical probe. The critical probe constituted a face of a certain likeness to the target face in half of the streams of each block, and a face of a certain likeness to a non-salient control face in the other half of streams. For every successive 12 streams in each block, the likeness of the probes to the respective target/control face increased by 10%. At the end of each stream, participants answered questions via key-presses. Specifically, they indicated the sex of the last face in the stream (1 for male, 2 for female); whether the target face appeared (1 for present, 2 for absent); and how confident they were in their responses, along a scale from 1 (not sure at all) to 6 (completely sure). This ensured maintained attention to the task and retrieved information about the target search. The duration of the experiment for each participant was approximately 70 minutes.

**Planned analysis**

The proposed study will comprise group-level and individual-level analyses of the data obtained from Aviles and Bowman’s experiment – comparing electrophysiological responses to inherently-salient male, inherently-salient female, and incidentally-salient male face stimuli, each at 10 different salience strengths, with responses to non-salient control face stimuli.

**Pre-processing**

The collected EEG data was digitised at 2048Hz and filtered with a low-pass of 100Hz, at the time of recording.

In order to exclude extraneous artifacts from the collected EEG recordings, while retaining a maximal portion of useable data, we will employ Independent Component Analysis (ICA). This works to separate the multivariate EEG signal into individual sources, from which those corresponding to artifacts such as eye-blinks, muscle activity and electrical noise can be identified and removed.

We will also use a Fully-Flattened Average approach (FuFA) to specify the regions of interest (ROI) for each participant’s ERPs, to allow for individual-level analyses of responses to the different face stimuli. This data-driven method has been shown to avoid the inflation of Type 1 error rates associated with EEG’s multiple comparisons (Bowman et al., 2020).

**Data analysis**

Although the experimental design allows for a 2×3×10 analysis of variance (ANOVA) – examining the differences and interactions between responses to faces of each salience type, at each salience level, and responses to non-salient faces – the implementation tool that we will use (FieldTrip) does not allow for such complex comparisons. We will therefore achieve this using multiple tests of difference, in the form of cluster-based two-sample permutation tests.

For the group-level analysis, cluster-based paired-sample permutation tests will be used to assess the difference between the amplitudes of ERPs in response to faces of no salience (control probes) with responses to faces of inherent salience (Donald Trump/Meghan Markle) and faces of incidental salience (non-famous male target probe), at each grade of salience, across the sample data. For the individual-level analysis, cluster-based permutation versions of independent two-sample t-tests will be used to make the same comparisons within each participant’s individual data.

These cluster-based permutation procedures will work by first combining the adjacent spatial and temporal components of the given EEG data into connected sets. This will be achieved by using t-tests to compare the ERPs at each electrode and timepoint of each salient face condition (Donald Trump/Meghan Markle/incidentally-salient face) with the ERPs at each electrode and timepoint of the non-salient control face conditions (target-absent condition). Significant t-scores of adjacent electrodes/time-points will be summed to give cluster-level scores. 1000 permutations will then be run, simulating as many hypothetical ERPs as there were observed in the experiment, at every electrode and timepoint, for each condition. Cluster-level scores will be similarly calculated for these hypothetical ERPs, using the most extreme to generate the null distribution. If the proportion of distribution scores equal to or greater than the originally-observed cluster scores (the p-value) constitutes less than 5% (alpha = 0.05), we will be able to determine the difference between the two given conditions as significant.

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