Attentional Bias in Relation to Negative and Expectancy Violating Stimuli: A Divergence Between Theory and Research

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Acknowledgements

I would first like to thank my supervisor, Mr. Michael Cleary-Gaffney. For the sake of brevity I will say this: without Mr. Cleary-Gaffney's pragmatic guidance I would likely still be ranting on about theoretical principles or, at best, still analysing skin conductance data. Indeed, this work would not have been possible if not for his many recommendations and constant advice. I should also thank the many excellent educators at NCI who have helped me develop as a student and who have managed to put up with my extemporaneous and outspoken personality throughout the years. Finally, I would like to thank my participants who took the time to complete my study (I know, it was pretty boring).

> "It is also a good rule not to put overmuch confidence in the observational results that are put forward until they are confirmed by theory"-Sir Arthur Eddington

Abstract

Aims: The purpose of this study was to compare attentional orienting responses to both negative and expectancy violating stimuli. This was done in an attempt to reconcile the information theoretic Free Energy Principle (Friston, 2010) account of attention with the established empirical literature. In addition, we sought to explore the relationship between personality traits of neuroticism and psychoticism with responses to expectancy violating stimuli.

Method: Fifteen (n = 15) undergraduate psychology students viewed angry, neutral, and expectancy violating faces, while heart rate and skin temperature indices of orienting were measured. Personality traits were assessed using the Eysenck Personality Scale-Revised (EPQ-R; Eysenck, Eysenck, & Barrett, 1985). Participants also rated the valence of the presented faces using a 7-point likert scale (1 = negative; 7 = positive).

Results: Expectancy violating stimuli resulted in a non-significant reduction in heart rate over negative and neutral faces, M =-2.69, SE = 2.41, $p > .05$. The expectancy violating faces were also rated significantly more positive than negative faces, M = 2.25, SE = .25, $p < .01$. No significant relationship was found between physiological measures of orienting and personality traits, although a negative trend was found between orienting and neuroticism for both heart rate (r = -.29) and skin temperature (r = -.32) measures.

Conclusion: Lack of statistical power and choice of orienting measure may have precluded the detection of significant differences between stimuli. Furthermore, the heterogeneous nature of personality traits may have prevented the detection of any statistical relationship with attentional orienting. Implications are discussed below.

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Introduction

The sensory areas of the brain process vast quantities of information from our environment, yet only a small amount of this information reaches cognitive awareness associated with attention (Ungerleider, 2000). Indeed, information theoretic approaches to the study of attention have emphasised the limited capacity nature of this cognitive ability (Broadbent, 1958). As such, filtering mechanisms in the brain allow only significant information access to attention (Kastner et al., 2001).

Importantly, recent theoretical approaches, namely under the information theoretic Free energy principle (Friston, Kilner, & Harrison, 2006), have cast attention as the process of inferring the precision of sensory prediction error (Friston & Feldman, 2010). Of relevance to the current study, attention also involves orienting responses towards information dense or unexpected features in the environment (Pratt & Friston, 2017). Crucially, information is defined in relation to the probability of receiving some data (see, Shannon, 1948), which, in this context, means that unlikely sensory data contain more information than highly probable data.

In contrast, much of the empirical research in the area of attention has focused on the influence of negative or threatening stimuli in generating attentional responses. Indeed, an extensive body of research indicates that emotional stimuli lead to greater and more consistent attentional responses than neutral stimuli (see, Rozin & Royzman, 2001). This is also reflected in the fact that negative stimuli induce greater orienting responses that are resistant to habituation (Bradley, 2009). Moreover, aberrant attentional responses to negative stimuli have also been implicated in a number of psychopathologies, such anxiety and psychosis (Van Bockstaele et al., 2014; Jang et al., 2016).

It is not clear how these two approaches relate to each other. The theoretical Free Energy approach posits that organisms attend to features in the environment that are rich in information. On the other hand, empirical research has emphasised the role of emotional stimuli in generating attentional responses. What follows is an attempt to reconcile these two views.

The Free Energy Principle and Attention

The Free Energy Principle (Friston, Kilner, & Harrison, 2006) has been proposed as a unified theory of the brain (Friston, 2010; Hohwy, 2015). A fundamental premise of this theory is that organisms resist a tendency towards disorder by maintaining a limited number of behavioural and sensory states (Friston, 2010). This can be roughly equated to the maintenance of some homeostatic bound (see, Friston, 2010, for a non-mathematical discussion). To this end, it is imperative that organisms avoid surprising or unexpected interoceptive and exteroceptive sensory states, as the long-term average of surprise is entropy (disorder) (Friston, 2010). Here, a surprising sensory state might range from the sensation of hunger to seeing a coworker in an unusual context.

To keep surprise (and therefore, entropy) at a minimum, an organism maintains a probabilistic model of its environment; the parameters of which are optimised in a bayesian fashion (Friston, 2009, 2010). What emerges is a predictive hierarchical model of the environment that encodes a number of contingencies and statistical regularities (Friston, 2009, 2010). The divergence between the expected data under this model and the actual sensory data encountered by the organism is referred to as the bayesian surprise, which is the precise quantity by which the organism's model needs to be updated. Importantly, bayesian surprise can only be inferred using another quantity known as variational free energy (Feynman, 1972; Friston, 2010)

In the brain, free energy is instantiated in the form of prediction error (Friston, 2009, 2010). In a hierarchical model, neurons encoding prediction error synergistically interact with neurons encoding higher level conditional expectations (see, Bogacz, 2017, for a mathematical tutorial). The result of this is a hierarchical optimisation scheme, in which lower level prediction errors update higher level beliefs about the environment (see, Friston, 2010).

Attention, in this scheme, is tasked with assessing the reliability or precision of prediction errors in a stochastic (noisy) environment (Friston & Feldman, 2010). This role is important, given that prediction errors drive updates of internal models. The role of attention in perception can be likened to a t-test, where the difference between groups (prediction error) is divided the variance (inverse precision). Simply, attention assigns weight to prediction errors. This conceptualisation explains much of what is known about attention in terms of behavioural and electrophysiological findings (see, Friston & Feldman, 2010, for a discussion).

Crucially, to incorporate this precise sensory information into one's model, the organism's sensory organs must be directed towards the source of the prediction error (i.e. saccadic eye movements) (Pratt & Friston, 2017). While this action may temporarily increase surprise over sensory states, the active sampling of novel or expectancy violating features has the effect of minimising surprise over future sensory states, thus serving an epistemic value (Friston et al., 2015). This account of attentional orienting is also congruent with other theoretical accounts that relate visual search to areas of the visual field that contain more sensory information (Bruce & Tsotsos, 2009).

While the free energy account of attention seems to have explanatory power in the field of neuroscience (see, Hohwy, 2015), there is little information that links this account with that of observations of attentional bias for emotional stimuli.

Orienting Responses and Emotion

Orienting has been termed as the “natural selective attention” (Bradley, 2009). Furthermore, a number of physiological indices have been associated with the orienting response. These include, elevations in electrodermal activity (Sokolov, 1963), decreases in heart rate (Graham & Clifton, 1966), and more recently identified, increases in pupillary dilation (Bradley, Miccoli, Escrig, & Lang, 2008).

Compared to neutral pictures, changes in electrodermal activity are greater for negative pictures (Bradley, Lang, & Cuthbert, 1993). According to Bradley and colleagues (1993), habituation to repeatedly presented negative pictures was slower than that for neutral pictures. A similar pattern has been found for other physiological measures when negative and neutral stimuli are compared (Bradley, 2009). For example, Bradley and colleagues (2008) found that negative stimuli lead to heightened pupillary dilation relative to neutral stimuli. Greater heart rate deceleration is also seen in animals when viewing negative information, which has been associated with increased sensory intake (Bradley, Codispoti, Cuthbert, & Lang, 2001).

Physiological measures of orienting have also been associated with personality traits. For example, trait neuroticism has been shown to predict greater physiological responses to aversive stimuli (Vogeltanz & Hecker, 1999). Conversely, self reported psychopathy in adulthood is negatively related to physiological arousal for fear stimulus (Glenn, Raine, Venables, & Mednick, 2009). Abnormalities in physiological responding have also been observed in clinical populations. Indeed, some populations of schizophrenic patients fail to show phasic orienting responses, whereas others show normal phasic activity but higher tonic activity (Öhman, 1981). Additionally, anxiety has been associated with increased orienting towards threatening stimuli, resulting in the development of attentional bias modification treatments (Mogg & Bradley, 2018); albeit, with limited evidence for any therapeutic benefits (Mogoaşe, David, & Koster, 2014).

The Relationship Between Emotional and Expectancy Violating Stimuli

While it can be argued that the neutral stimuli used in the above mentioned experiments are novel, given that the participant would never have seen the exact stimulus before, it is not likely that they violate any previously acquired expectations. Indeed, there is a subtle distinction between novel and expectancy violating or deviant stimuli. Novel stimuli includes objects in the environment that have never been encountered before, whereas expectancy violating stimuli refers to objects that violate or deviate from a previously acquired conceptual or epistemic relationship (Schomaker & Meeter, 2015).

Importantly, expectancy violating stimuli have been shown to consistently elicit orienting responses (see, Proulx & Inzlicht, 2012). For instance, Sleegers, Proulx, and Beest (2015) found that the presentation of incongruous playing cards (i.e., a red spade) lead to increased pupil dilation in participants. However, very few studies have directly examined this effect in relation to emotional stimuli.

Of relevance, there is some evidence that expectancy violating stimuli can modulate emotional responding. Indeed, one interesting study by Grupe and Nitschke (2011) found that electrodermal activity was heightened during the viewing of a negative pictures when preceded by an uncertainty cue, compared to aversive pictures preceded by a certainty cue. Crucially, the authors of this study concluded that the unexpectedness of the aversive picture, when it was preceded by the uncertainty cue, may have potentiated physiological arousal. In terms of positive emotion, animals have been shown to have a greater appetite when food was found in an unexpected location compared to an expected location (Roitman, van Dijk, Thiele, & Bernstein, 2001).

Perhaps the only study to ever directly compare negative and expectancy violating stimuli was a recent study Proulx, Sleegers, & Tritt (2017). These researchers compared pupillary dilation responses for angry, upside down, and thatcherised faces (a type of visual illusion). Interestingly, they found that expectancy violating, thatcherised faces lead to increased pupillary dilation 500-1500 milliseconds after stimulus onset. Conversely, physiological responses for negative stimuli were seen during periods in excess of 1500 milliseconds. The authors interpreted this as evidence for an attentional bias for expectancy violating information, as this type of stimulus lead to earlier orienting responses.

Theoretical and Practical Implications

Proulx and colleagues' (2017) result seems to contradict the notion that there is an attentional bias for negative stimuli. What's more, this finding may be in line with the free energy account of attention, as expectancy violating features seem to lead to more pronounced orienting responses (Pratt & Friston, 2017). Importantly, this finding may present an opportunity to reconcile both the theoretical and empirical approaches to attention.

One possibility concerning the empirical approach, is that the observed attentional biases for negative stimuli are due to the relative infrequency of this type stimulus in the environment. As such, negative features would contain more information and thus, would engender greater attentional responses over neutral stimuli. However, this does not explain why negative stimuli are resistant to habituation (Bradley, 2009). Also, it does not explain why physiological responses are greater for negative, relative to expectancy violating, features during periods in excess of 1500 milliseconds (Proulx, Sleegers, & Tritt, 2017).

Another possibility concerns more recent formulations of the Free Energy Principle, which have cast emotional valence in terms of the predicted rate of change of free energy over time (see, Joffily & Coricelli, 2013; Kiverstein, Miller, & Rietveld, 2017). For instance, a negatively valenced stimulus would inform the organism that free energy is increasing over time. If responses to expectancy violating stimuli are shown to precede negative stimuli, this implies that the rate of free energy is encoded over longer latencies and perhaps at higher levels of abstraction than deviant stimuli. Simply, this means that emotional stimuli may only contain information at higher levels of a given neuronal hierarchy. In addition, this also means that surprise (free energy) at lower levels of the hierarchy can influence emotional responses at higher levels.

In practical terms, such a scheme might explain why attentional bias modification interventions for anxiety have limited efficacy (Cristea, Kok, & Cuijers, 2015). Indeed, heightened attention to negative features in the environment may be the result of a generalised sensitivity to expectancy violating features in the environment, which could be related to innate personality features. Similar ideas have been presented in the Entropy Model of Uncertainty (see, Hirsh, Mar, & Peterson, 2012), where anxiety is the result of uncertainty (equivalent to information entropy) about perception and action. A substantial literature has already been dedicated to the latter case, whereby the activation of two similarly weighted goals engage the behavioural inhibition system related to anxiety (see, Gray & McNaughton, 2000; McNaughton, 2006).

The Current Study

The main aim of the current study is to find converging evidence for Proulx and colleagues (2017) findings of earlier attentional responses for expectancy violating stimuli. This study used pupil dilation as a measure of attentional orienting, a relatively novel index of bottom up attention (see, Eckstein, Guerra-Carrillo, Miller-Singley, & Bunge, 2017). Hence, it would be expedient to relate these findings to other well-established indices of orienting.

To this end, heart rate deceleration will be used to measure orienting. As mentioned earlier, heart rate deceleration has been associated with increased sensory intake (Bradley et al., 2001). Furthermore, decreases in heart rate are generally are generally associated with concomitant decreases in skin temperature (Kreibig, 2010). Like Proulx and colleagues study (2017), however, we will use thatcherised faces as expectancy violating stimuli. These are simply faces that are presented upside down and with inverted local features (Thompson, 1980), thus undermining previously learned facial representations. Moreover, reactions to this type of face will be compared to that of angry and neutral faces.

Importantly, previous studies have found that expectancy violating stimuli, such as incongruous playing cards and discrepant stroop task trials, lead to initial physiological responses between 500 and 1500 milliseconds (Sleegers et al., 2015; Rondeel, van Steenbergen, Holland, & van Knippenberg, 2015). Indeed, these changes in physiological arousal are likely mediated by the anterior cingulate cortex (Peters, McEwen, & Friston), a key node in both the orienting response (Williams et al., 2000) and in the assessment of information entropy (Fan, 2014). Hence, we predict that decreases in heart rate and skin temperature will be greatest during a period of 500-1500 milliseconds upon presentation of expectancy violating stimuli compared to negative and neutral stimuli.

To make sure that any findings of heightened attention for expectancy violating stimuli are not simply due to them being perceived as negative, we will also examine the valence of the stimuli used. Indeed, if expectancy violating stimuli are not rated negatively, this should preclude the possibility that increased physiological responses are due to them being perceived as negative. Thus, we propose that expectancy violating stimuli will be rated less negatively than negative stimuli.

Finally, this study aims to analyse the relationship between attentional responses to expectancy violating stimuli and personality traits of neuroticism and psychoticism. Neuroticism is a stable personality trait that is reflected in a heightened sensitivity towards stressors and negative emotion (Jeronimus, Kotov, Riese, & Ormel, 2016). In addition, trait psychoticism is thought to be a predictor of psychosis (Ettinger et al., 2013) and is negatively related to learning under punishing contingencies (Corr, Pickering, & Gray, 1997).

Interestingly, no research to date has examined these traits specifically in relation to expectancy violating stimuli. Nevertheless, a recent study has linked post-traumatic stress disorder, a condition characterised by heightened vigilance and anxiety, to increased mismatch negativity event related potentials (ERP) to deviant auditory tones (Bangel et al., 2017). Indeed, mismatch negativity ERPs seem to be related to involuntary attentional switching to deviant stimuli (Näätänen & Escera, 2000). Furthermore, this activity is diminished in psychotic patients (Kircher et al., 2004; Wynn et al., 2010). Given their association with psychopathology, we predict that neuroticism and psychoticism will be positively and negatively related to physiological arousal for expectancy violating stimuli, respectively.

Methods

Participants

Fifteen (n = 15) third year psychology students from the National College of Ireland took part in this study. Participants were selected using a convenience-based sampling strategy. In terms of sample characteristics, most participants were female (n = 9) and were aged between 20 and 23 years (*M* = 21.6, *SD* = 0.99). Full informed consent was given by each participant before partaking in the study.

Materials/Apparatus

Face Stimuli

The face stimuli used in this experiment were kindly supplied by Proulx, Sleegers, and Tritt (2017). Three classes of stimuli were used: negative, neutral, and expectancy violating. Stimuli were presented in portrait format (Height: 115.8mm; Width: 77mm).

For the negative and neutral stimuli angry faces and neutral faces were used, respectively. These faces were originally from the Radboud Faces Database (RaFD) (Langner et al., 2010), in which the stimuli have been validated with respect to valence. We selected 10 caucasian adult male and female faces (though not in equal number) for this study. Each face appears more than once to the participant throughout the experiment under different conditions. For example, participants will see the same face under both angry or neutral conditions at different times throughout the experiment.

For expectancy violating stimuli, thatcherised faces were used. These faces were generated by Proulx and colleagues from neutral faces that were taken from the RaFD database (Langner et al., 2010). The ‘Thatcher effect’ (Thompson, 1980) is essentially a visual illusion, whereby faces are inverted 180° and the mouths, eyes, and eyebrows are presented incongruously right side up. Ideally, participants will not have encountered this class of stimuli relative to negative or neutral faces, thus rendering them expectancy violating.

Physiological Instruments

Heart rate and skin temperature were measured using the ADinstruments pulse transducer and temperature probe, respectively. The pulse transducer converts mechanical pressure to electrical analog signals, which are directly recorded by an ADinstruments powerlab (26T) system. Heart rate was recorded in beats per minute (bpm). Importantly, the criteria for a heart beat was based upon the detection of an exponential sine function in the data, more specifically, the interval between two sine functions functions. This was supposed to represent the R-R interval between heartbeats.

The temperature probe detects changes in skin temperature over a 0-50℃ range. This instrument is coupled to an ADinstruments thermistor pod, which allows for continuous acquisition of temperature data. Both physiological measures were analysed with LabChart7 software.

Self Report Questionnaire

Neuroticism and psychoticism personality traits were measured using items from the short form version of the Eysenck Personality Questionnaire-Revised (EPQ-R; Eysenck, Eysenck, & Barrett, 1985). The short form of the scale is composed of 48 yes or no type questions that index personality traits of neuroticism, extraversion, and psychoticism--as well as a separate lie scale to detect socially desirable responding (Barrett, Petrides, Eysenck, & Eysenck, 1998). For the purposes of this study, only the scale items measuring neuroticism and psychoticism were used.

The neuroticism scale of the EPQ-R (Eysenck, Eysenck, & Barrett, 1985) contains 12 items relating to emotional lability and anxious attributes (e.g., “Would you call yourself a nervous person?”). On the other hand, the psychoticism scale contains 12 items that address hostility and antisocial dispositions (e.g., “Would you like other people to be afraid of you?”). The neuroticism scale had good internal reliability (α = .87), whereas the psychoticism scale had poor internal consistency (α = .18).

Slideshow Presentations

Two Powerpoint slideshow presentations were created for this experiment. The first was pre-timed and contained 10 of each face type (angry, neutral, and expectancy violating) arranged in pseudo-random order. Importantly, the same pseudo-random pattern was used for all participants. To randomise the stimuli, each face type was numbered (angry = 1; neutral = 2; expectancy violating = 3) and entered into an online random list generator at www.random.org/lists/. The output of this program is dictated by random atmospheric noise and thus free of systematic bias.

The first slideshow consisted of 3 elements: a fixation cross, a face stimulus, and an interstimulus blank screen. These were intended to occur for 1, 2, and 10 seconds, respectively. This ensemble constituted a single trial and was supposed to be a total of 13 seconds long, however, there was a slight delay in transition time between the slides. This lead to each trial being 13.8 seconds in total.

The second presentation consisted of 5 negative, 5 neutral, and 5 expectancy violating faces (15 faces in total). These faces were chosen selected from the 10 previously chosen faces from the RaFD (Langner et al., 2010). A similar randomisation procedure was used. The purpose of this presentation was to allow the participants to make judgements regarding the valence of the faces they viewed in the first slideshow.

Both slideshows were presented on a Lenovo Ideapad 100 laptop with a 15.6” screen and using microsoft Powerpoint 2016 software.

Valence Judgements

Judgements regarding the emotional valence of faces were recorded on a likert scale ranging from 1 to 7. A rating of 1 indicated a negative judgement, 4 indicated a neutral judgement, and 7 indicated a positive judgement. Likert scales were printed on a sheet of paper.

Design

This study employed a within participant quasi-experimental design. Indeed, participants were all presented with the same face stimuli, in which angry, neutral, and expectancy violating stimuli were independent variables. As dependent variables, within individual reactivity in heart rate and skin temperature were compared. Differences in valence judgements for each face type were also compared. Finally, correlations were examined between self reported personality traits (neuroticism and psychoticism) and physiological reactivity.

Procedure

In the first part of the study, participants were instructed to fill out the EPQ-R questionnaire in the laboratory. Upon completion of the questionnaire, participants were asked to provide their non-dominant hand. The pulse transducer and temperature probe was attached to the middle and index fingers of this hand, respectively. This was necessary for the second phase of the study.

During this part of the study, participants were sat in front of the laptop where the slideshow was to be played. Physiological data was recorded during a 3 minute baseline period, where participants looked at a blank screen. After three minutes, a fixation cross appeared for 1 second to signal the onset of a stimulus. Each face was presented for 2 seconds, followed by a 10 second interstimulus blank screen. This interstimulus period was intended to allow physiological measures to return to baseline levels. Physiological data was recorded for approximately 10 minutes in total. This subsumed the baseline period and the 30 trial blocks.

For the third phase of the study, participants were asked to view the second slideshow. In addition, participants were given a pen and the sheet of paper with the likert scales and instructed to rate how they perceived the valence of the faces they saw as they parsed through the slideshow. Participants were free to complete this task at their own pace, as the slideshow was not pre-timed.

Data preparation and analysis

For both physiological measures, data was acquired from 500 milliseconds to 1500 milliseconds after stimulus onset. This data was sampled automatically using LabChart7 software, which sampled a 1 second period every 13.8 seconds (in keeping with the observed slideshow presentation times). The outputs from the 30 trials (per participant) were then exported to SPSS.

In SPSS, the data was analysed for outliers and extreme scores, defined as scores over three standard deviations from the mean. Importantly, these outliers were identified with respect to each individual's data, rather than the overall distribution of data. This was because physiological data, namely heart rate, varies substantially between participants. For instance, an outlier relative to one individual's data may be in the normal range for another's. Also, only within individual variance in physiological measures were relevant during this study.

When between individual variability was relevant, such as during correlational analyses, a change score was calculated. This simply involved subtracting the average score for physiological measures from expectancy violating scores. This was done for both heart rate and skin temperature.

Results

Descriptives

Descriptive statistics, including means (*M*), standard deviations (*SD*), and 95% confidence intervals (95% CI) are provided in Table 1 for physiological data. Kolmogorov-Smirnov tests of normality indicated that all of the 12 physiological variables in Table 1 were normally distributed ($p > .05$).

Table 1. *Descriptive statistics for physiological variables.*

Variables	Mean (95%CI)	Std. Error	*SD*	Range
HR Negative	143.91 (115.48-172.34)	13.26	51.34	80.59-230.28
HR Neutral	143.04 (114.77-171.31)	13.18	51.05	79.82-241.52
HR EV	141.22 (113.34-169.1)	13	50.34	80.48-225.11
°C Negative	28.64 (26.08-31.19)	1.19	4.61	22.01-34.3
°C Neutral	28.69 (26.12-31.25)	1.20	4.64	22.03-34.3
°C EV	28.66 (26.09-31.24)	1.20	4.65	21.98-34.19
ΔHR	1.82 (-2.92-6.56)	2.21	8.55	-16.15-18.15
Δ°C	.02 (-.04-.08)	.03	.11	-.31-.14

Note. HR = Heart Rate; EV = Expectancy Violating; °C = temperature (in degrees celsius); Δ = change; Neg = Negative.

Descriptive statistics for self reported data are provided in Table 2. Kolmogorov-Smirnov tests of normally found that Psychoticism and mean valence ratings for expectancy violating faces were non-normally distributed ($p < .05$).

Table 2. *Descriptive statistics for personality traits and self reported valence ratings.*

Variables	Mean (95%CI)	Std. Error	*SD*	Range
Neuroticism	6.33 (4.15-8.52)	1.08	3.94	0-12
Psychoticism	3.67 (2.72-4.62)	.44	1.72	1-8
Angry faces	2.05 (1.70-2.40)	.16	.63	1.20-3.60
Neutral faces	3.97 (3.80-4.15)	.08	.32	3.40-4.60
EV faces	4.31 (3.84-4.77)	.22	.83	3.60-7

Note. EV = Expectancy Violating.

Inferentials

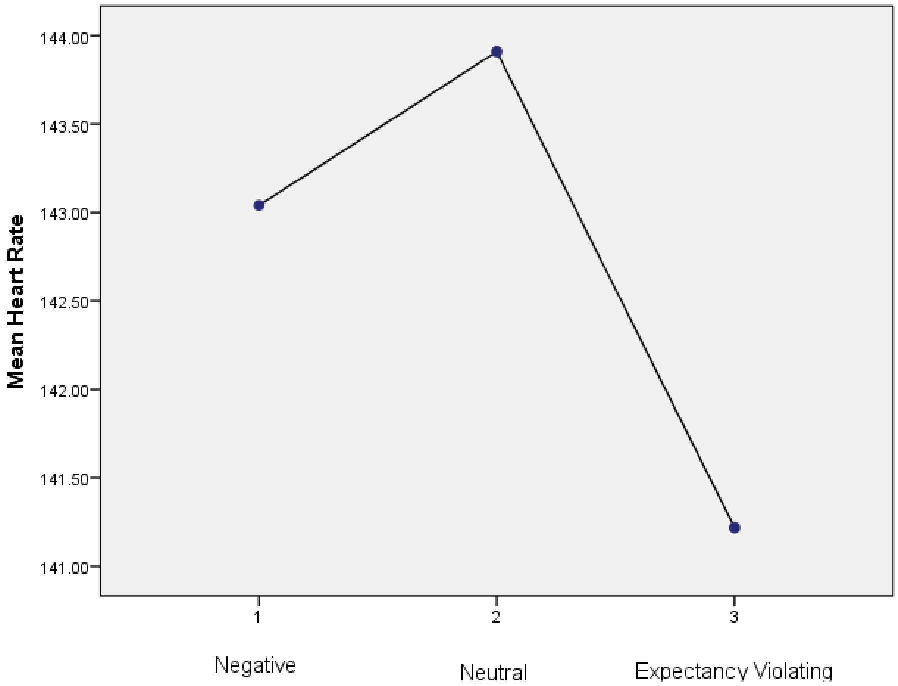
<u>Hypothesis 1</u>

To test the first part of hypothesis 1, that expectancy violating stimuli will result in a greater decrease in heart rate relative to negative stimuli, a repeated measures ANOVA was carried out to test for differences in heart rate for neutral, negative, and expectancy violating stimuli. Mauchly's test of sphericity indicated that this assumption was met ($p > .05$). The, however, test indicated no significant differences in heart rate between these conditions, F (2, 28) = .844, $p = .44$.

Although non-significant, post-hoc tests found that there was a slight trend towards lower heart rates for expectancy violating stimuli relative to both neutral (M =-2.69, SE = 2.41) and negative stimuli (M = -1.82, SE = 2.21).

To test the second part of hypothesis 1, that expectancy violating stimuli will result in a greater decrease in skin temperature relative to negative stimuli, another repeated measures ANOVA was used. This time differences in skin temperature were analysed. The assumption of sphericity was not met ($p < .05$) and a Greenhouse-Geisser correction was applied. This model was also non-significant, F (1.15, 16.19) = .40, p = .57. Overall, both tests reject hypothesis 1.

figure 1.

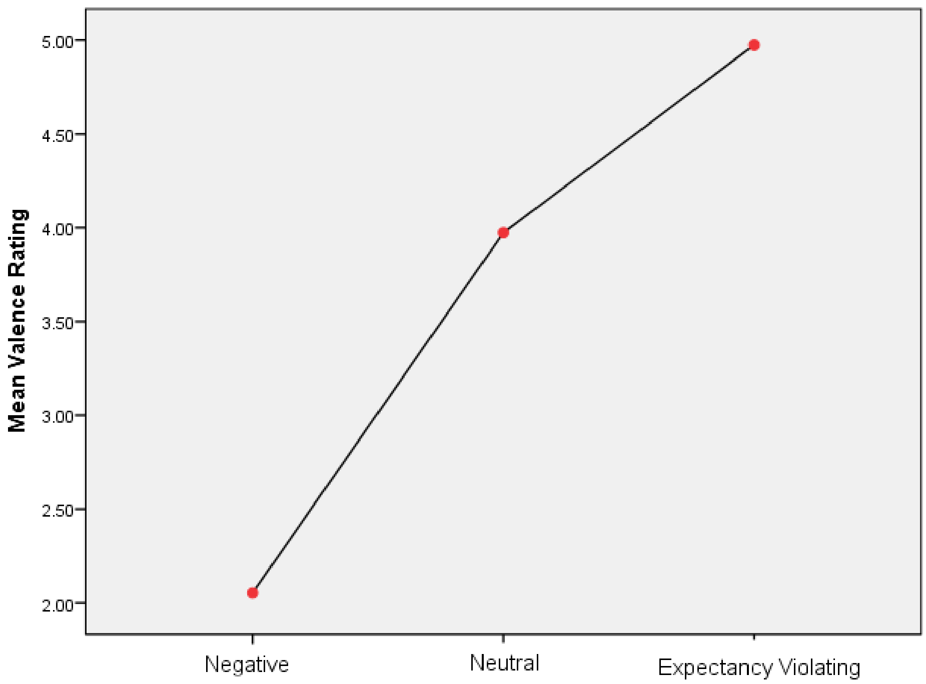


Hypothesis 2

To test the second hypothesis, that expectancy violating stimuli will be rated more positively than negative stimuli, a repeated measures ANOVA examined differences in ratings between negative, neutral, and expectancy violating stimuli. While the ANOVA is a parametric test and one of the variables was non-normally distributed, it was used anyway, given its robustness to violations of normality (Harwell, Rubinstein, Hayes, & Olds, 1992). This model was significant, $F(2, 28) = 60.37$, p <.01 and the effect size was very large (partial η^2 = .895)

Post-hoc tests used a Bonferroni correction to adjust α for multiple analyses. Significant differences were found between expectancy violating stimuli and negative stimuli (M = 2.25, SE = .25, p < .01). This indicates that expectancy violating stimuli were rated as more positive than negative stimuli. Another significant difference was found between neutral and negative stimuli (*M* = 1.92, *SE* = .19, *p* < .01). This also indicates neutral stimuli were rated more positively than negative stimuli. Interestingly, the differences between expectancy violating and negative stimuli were larger than that between negative and neutral stimuli. However, there were no significant differences between neutral and expectancy violating stimuli (*M* = -.33, *SE* = .22, *p* = .44).

figure 2.



Hypothesis 3

To investigate the relationship between personality traits and physiological responses to expectancy violating stimuli, correlational analyses examined the associations between trait neuroticism and changes in physiological parameters. The relationship between neuroticism and change in heart rate was non-significant, *r* = -.29, *p* = .30. The relationship between skin temperature change and neuroticism was also non-significant, *r* = -.32, *p* = .25.

In addition, the relationship between trait psychoticism and change in physiological measures for expectancy violating stimuli was examined. Given that trait psychoticism was non-normally distributed, the non-parametric Spearman's rank order test was used. There was no association between psychoticism and change in heart rate, $\rho = -.01$, $p = .97$. The relationship between psychoticism and change in skin temperature was also non-significant, $\rho = .02$, $p = .95$. These results show that there was no relationship between personality traits and attentional responses to expectancy violating stimuli.

Discussion

For the most part, the results of this study did not support our proposed hypotheses. The possible reasons for this are explained below.

Across three conditions (that is, negative, neutral, and expectancy violating conditions) we compared the degree of orienting in participants, using heart rate and skin temperature as indices of attentional responsivity. However, there were no significant physiological differences observed between any of these conditions. This contrasts with both our hypothesis and the current literature. Indeed, our findings seemingly contradict the previous studies that found enhanced orienting to negative stimuli over neutral stimuli (Bradley, 2009; Bradley et al., 2001). Furthermore, these results also contradict the recent observation of heightened orienting to expectancy-violating relative to negative stimuli (Proulx, Sleegers, & Tritt, 2017).

Nevertheless, visual inspection of the heart rate data (see, figure 2.) indicates that there was a trend towards lower heart rates for expectancy violating information relative to negative information; congruent with our hypothesis and the findings of Proulx and colleagues (2017). This raises the possibility that the current study may have simply been underpowered and thus, unable to detect significant differences between conditions. Furthermore, this issue could have been exacerbated by the rapid habituation of heart rate responses to both novel and threatening stimuli (see, Bradley, 2009).

In contrast to this explanation, our lack of significant results, at least with respect to heart rate, could be due to the fact that decreases in this physiological measure are mediated by the parasympathetic nervous system (Berntson, Boysen, Bauer, & Torello, 1989). While still a component of the orienting response, heart rate deceleration may operate over different time frames than other, sympathetically mediated responses, such as pupil dilation (Eckstein et al., 2017). As such, our sampling period (500-1500 milliseconds) may not have adequately captured responses to stimuli. Indeed, the sampling period used in the current study was based off of other studies that had found heightened responses to expectancy violating stimuli using sympathetically mediated measures (Proulx, Sleegers, & Tritt, 2017; Sleegers et al., 2015; Rondeel, van Steenbergen, Holland, & van Knippenberg, 2015).

Another possibility is that the face stimuli used were similarly perceived, thus, unlikely to yield any significant differences in attention. Our analysis of the self reported valence of the stimuli used renders this possibility unlikely, however. In support of our hypothesis, participants rated angry faces as more negative than both the neutral and the thatcherised faces. Interestingly, the thatcherised or expectancy violating faces were rated more positively than the neutral faces, although this difference was not significant.

In regards to valence, it is possible that the use of full informed consent influenced participant's ratings of the faces. Indeed, on the information sheet (see, Appendix A) participants are told that they would be viewing negative and expectancy violating faces. This fact may have influenced our participant's decisions when rating the valence of the faces during the second slideshow. Nevertheless, it should be mentioned that the face stimuli used in this study have previously been validated with respect to valence (Langner et al., 2010; Proulx, Sleegers, & Tritt, 2017).

We also tested the relationship between personality traits and changes in physiological arousal for expectancy violating stimuli. Contrary to our hypothesis, however, there was no significant correlation between personality traits of neuroticism and psychoticism, and changes in arousal. Although there was a non-significant negative relationship between neuroticism and both physiological measures, this was in the opposite direction to what was predicted. That is, higher neuroticism predicted lower change scores in physiological arousal. This relationship may reflect the well established relationship between neuroticism and depression (Jeronimus et al., 2016). Indeed, depression has previously been associated with decreased reactivity to novel sounds, measured by P3 EEG activity (Bruder et al., 2009), an index of orienting (Bradley, Keil, & Lang, 2012). This conclusion is tentative, however.

No discernable pattern was found between changes in physiological arousal and trait psychoticism. This may be due to the trait's lack of internal consistency (α = .18), which itself may be due to the heterogeneous nature of the sub-traits that constitute this super-factor trait (Howarth, 1986). Indeed, psychoticism sub-traits may exert a positive effect on attentional responses, whereas other may exert the opposite effect. For example, sensation seeking, a component of psychoticism, has been shown to correlate positively with electrodermal activity for novel stimuli (Neary & Zuckerman, 1976). In contrast, psychopathy, another construct associated with psychoticism (see, Zuckerman, Kuhlman, Thornquist, & Kiers, 1991), seems to be related to attentional hyporeactivity (Blair & Mitchell, 2008).

Implications and Directions for Future Research

Whether or not attentional responses to expectancy violating objects precedes that of negatively valenced stimuli is still an open question. Indeed, there was no statistical relationship to back up either the theoretical claims of an attentional bias for expectancy violating stimuli or for the empirically derived negativity bias. Nonetheless, it should be noted that this is only the second study to directly compare expectancy violating and negative stimuli in relation to attention. Further studies are needed to precisely understand the relationship between these classes of stimuli.

Future studies should attempt to use other measures of orienting to compare stimuli. For example, eye tracking studies have already shown that individuals fixate on more complex compared to simple compositions (Bradley, Keil, & Lang, 2012). Other studies could compare complex stimuli with negative stimuli in terms of reaction times to see which class of stimuli elicit quicker responses. Additionally, behavioural studies using attention related tasks, such as the no-go or attentional blink paradigms, could compare performance during presentation of emotional and novel features.

In the context of mental illness, researchers should take caution when trying to study the relationship between predictors of mental illness (i.e. personality traits) and attention. For example, trait neuroticism is predictive of both depression and anxiety (Jeronimus et al., 2016); each of which possibly leading to different attentional responses. The same argument can be made for trait psychoticism. The heterogeneity of such super-traits may blur statistical relationships. As such, researchers should use narrower measures of personality in future studies.

Conclusion

In summary, there was a trend towards lower heart rates for expectancy violating stimuli. However, were no significant differences in any physiological indices of orienting for negative, neutral, or expectancy violating stimuli. This could have been due to the lack of statistical power in the current study or our choice of physiological measure, namely heart rate, which may differ from other measures of orienting. Additionally, no significant relationship was found between measures of orienting and personality traits of neuroticism and psychoticism. What's more, the trend between neuroticism and orienting was opposite to what was expected. We tentatively attributed this to neuroticism's relationship to depression. Furthermore, we suggested that the heterogeneous nature of trait psychoticism precluded any correlation with orienting.

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Appendices

Appendix A

Information Sheet

Attentional Bias in Relation to Negative and Expectancy Violating Stimuli: A Divergence between Theory and Research

INVITATION

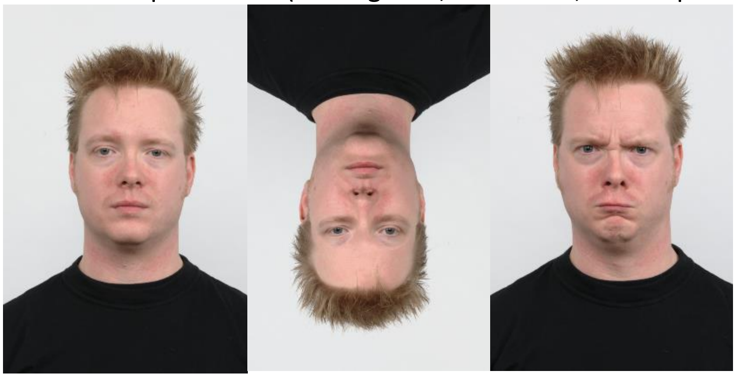
You are being asked to take part in a research aimed at understanding attentional responses, via heart rate and skin temperature measures, for expectancy violating stimuli. This research project will be conducted by Sean Kinsella, a third year undergraduate student at the National College of Ireland. In addition, this study is supervised by Michael Cleary-Gaffney. This project has received approval from the NCI ethics board.

WHAT WILL HAPPEN

Before the experiment, you will be assigned a participant ID number and asked to provide a number of basic details, such as age, gender, and handedness. In addition, you will be asked to fill out a self report questionnaire, measuring both neuroticism and psychoticism. Importantly, you will not be asked to provide any personal or identifying information.

For the next part of the experiment your physiological data will be recorded. The heart rate and skin temperature apparatus will be attached to the fingers on your non-dominant hand. Like the initial part of the experiment, you will be asked to view a number of face stimuli (10 angry, 10 neutral, and 10 expectancy violating), which will be arranged in a pseudo-random fashion. These will be presented as part of a single slideshow presentation that will proceed in a pre-timed fashion. For the first trial, you will view a blank screen for 120s, followed by a fixation cross for 1 second (this is to signal imminent onset of the stimulus), and then the face stimulus for 2 seconds. For later trials (there are 60 in total), you will view a blank screen for 10 seconds, then a fixation cross for 1 second, followed by the stimulus for two seconds. This cycle will repeat until completion of the experiment.

After this, you will be asked to view a number of face stimuli (5 angry, 5 neutral, and 5 expectancy violating/thatcherised faces) from a slideshow presentation. You will be asked to rate the emotional valence of each face on a seven point scale (1 = negative, 4= neutral, and 7= positive).



TIME COMMITMENT
The first part of the experiment, with the fixed pre-timed slideshow, will take approximately 16-17 minutes (though, this may not include the time taken to attach the apparatus for the physiological measures. The second part of this experiment may take around 5-10 minutes. However, this depends largely on the pace at which you wish to view and rate the stimuli. In total, this experiment is likely to take between 25 and 30 minutes of your time.

PARTICIPANTS' RIGHTS
You may decide to stop being a part of the research study at any time without explanation. You have the right to ask that any data you have supplied to that point be withdrawn/destroyed.

BENEFITS AND RISKS
Participation in this experiment involves the viewing of both emotional and expectancy violating stimuli to elicit physiological responses. While there is no well established risk, these types of stimuli may make you feel uneasy. In this case, you may inform the experimenter and withdraw from the experiment at once.

COST, REIMBURSEMENT AND COMPENSATION
Your participation in this study is voluntary.

CONFIDENTIALITY/ANONYMITY
The data we will collect will not contain any personal information about you, except for your sex, age, and handedness. In addition, the results of this experiment may be displayed at conferences or presentations etc. If you hold reservations about this, please inform the experimenter.

FOR FURTHER INFORMATION
For further information, you could consult with the principal investigator, Sean Kinsella at x14442578@student.ncirl.ie. The supervisor for this experiment, Michael Cleary-Gaffney will be glad to answer your questions about this study at any time. You may contact him at michael.cleary-gaffney@ncirl.ie or in his office on the second floor (in the research building).

Consent Form

CONSENT FORM

Attentional Bias in Relation to Negative and Expectancy Violating Stimuli: A Divergence between Theory and Research

In agreeing to participate in this research I understand the following:

This research is being conducted by Sean Kinsella, an undergraduate student at School of Psychology at the National College of Ireland

I have been informed as to the general nature of the study and agree voluntarily to participate in the study. I understand that this is not a clinical assessment.

I understand that all personal information and data provided by me over the duration of the study will be kept confidential. I understand that all my personal details will be kept separate from the data information. I understand that I will not be identified by name at any stage in the data analysis or in any publications.

I understand that I may refuse to participate or withdraw my participation and data at any time up until the publication date.

I understand that I can gain access to my data at my own discretion by contacting either the researcher Mr. Sean Kinsella or the project supervisor Mr Michael Cleary-Gaffney.

Supervisor

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I have also read and understand the information sheet provided with this consent form and I agree to participate in the research.

Signature of the Participant: ______________________________ Date: _______________

Appendix B

Valence Report Sheet

	Negative		Neutral		Positive		
1.	1	2	3	4	5	6	7
2.	1	2	3	4	5	6	7
3.	1	2	3	4	5	6	7
4.	1	2	3	4	5	6	7
5.	1	2	3	4	5	6	7
6.	1	2	3	4	5	6	7
7.	1	2	3	4	5	6	7
8.	1	2	3	4	5	6	7
9.	1	2	3	4	5	6	7
10.	1	2	3	4	5	6	7
11.	1	2	3	4	5	6	7
12.	1	2	3	4	5	6	7
13.	1	2	3	4	5	6	7
14.	1	2	3	4	5	6	7

15.

1	2	3	4	5	6	7