Biological Psychology 119 (2016) 42–45

Contents lists available at ScienceDirect

Biological Psychology

journal homepage: www.elsevier.com/locate/biopsycho

Short communication

Theta phase coherence in affective picture processing reveals dysfunctional sensory integration in psychopathic offenders

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ARTICLE INFO

Article history:
Received 10 March 2016
Received in revised form 14 June 2016
Accepted 29 June 2016
Available online 30 June 2016

Keywords:
Time frequency
Psychopathy
Sensory integration
Perception
Emotion

ABSTRACT

Psychopathic offenders are described as emotionally cold, displaying deficits in affective responding. However, research demonstrates that many of the psychopathy-related deficits are moderated by attention, such that under conditions of high attentional and perceptual load psychopathic offenders display deficits in affective responses, but do not in conditions of low load. To date, most studies use measures of defensive reflex (i.e., startle) and conditioning manipulations to examine the impact of load on psychopathy-related processing, but have not examined more direct measures of attention processing. In a sample of adult male offenders, the present study examined time-frequency EEG phase coherence in response to a picture-viewing paradigm that manipulated picture familiarity to assess neural changes in processing based on perceptual demands. Results indicated psychopathy-related differences in the theta response, an index of readiness to perceive and integrate sensory information. These data provide further evidence that psychopathic offenders have disrupted integration of sensory information.

1. Introduction

Prominent models of psychopathy attribute these offenders' failures of conscience, antisocial behavior, and insensitivity to affective information to a core emotion deficit. However, substantial evidence indicates that experimental context moderates these emotion deficits. Baskin-Sommers, Curtin, and Newman (2011) propose that this context specificity is associated with an early attention bottleneck that filters multidimensional information in serial, rather than simultaneously, thus hindering the fluid processing of information. Across experimental contexts, psychopathic offenders display normal responses to affective information when it is part of their goal-directed task or embedded in a perceptually simple display, yet their reactions to the same stimuli are deficient when their attention is allocated to an alternative goal or complex aspect of the situation (Baskin-Sommers, Curtin, & Newman, 2013; Decety, Chen, Harenski, & Kiehl, 2013; Meffert, Gazzola, den Boer, Bartels, & Keysers, 2013; Newman, Curtin, Bertsch, & Baskin-Sommers, 2010; Newman & Kosson, 1986; Sadeh & Verona, 2012).

Arguably the strongest evidence for the emotion deficit in psychopathy comes from research examining startle responses during picture viewing. In contrast to non-psychopathic offenders, who display startle potentiation during unpleasant pictures and startle inhibition during pleasant pictures, the startle potentiation to unpleasant pictures appears to be lacking in psychopathic offenders, particularly in offenders high on interpersonal-affective (Factor1) traits (Vaidyanathan, Hall, Patrick, & Bernat, 2011). However, Baskin-Sommers et al. (2013) demonstrated that by manipulating picture familiarity, psychopathic offenders displayed the classic deficit in emotion-modulated startle during novel pictures, but no deficit in emotion-modulated startle during familiar pictures.

Using explicit instruction or condition manipulations, previous work provides strong evidence of dysfunctional attention-emotion processing in psychopathy. It is possible, though, that an attention bottleneck can also affect perceptual and sensory processing (Kastner & Ungerleider, 2000). Previous research shows that the phase coherence of theta, particularly in parietooccipital and primary sensory cortices, represents a neural index of readiness to perceive and integrate sensory inputs, both across and within sensory modalities (Buzsaki, 2005; Lakatos et al., 2009). Moreover, theta phase coherence is modulated by familiarity, possibly indicating greater dynamic coordination in familiar conditions across

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http://dx.doi.org/10.1016/j.biopsycho.2016.06.011
0301-0511/

sensory domains (Miyakoshi, Kanayama, Iidaka, & Ohira, 2010).[1] The present study measured theta phase coherence, as an index of readiness to perceive and integrate sensory information, during the picture-viewing paradigm used by Baskin-Sommers et al. (2013). If readiness to perceive and integrate sensory information affects the efficient processing of affective information among offenders with psychopathy, then their theta inter-trial coherence (ITC), much like their defensive startle reactivity, should be impacted by the familiarity manipulation.

2. Methods

2.1. Participants

Ninety-nine incarcerated males between the ages of 18 and 45, with an IQ greater than 70, no clinical diagnoses of schizophrenia, bipolar disorder, or psychosis, and who were not currently using psychotropic medications were assessed for psychopathy and its related traits with the Psychopathy Checklist-Revised (PCL-R) (Hare, 2003) (see Table S1).

2.2. Task

Thirty-six pictures (12 unpleasant, 12 neutral, 12 pleasant) were selected from the International Affective Picture System (Lang, Bradley, & Cuthbert, 2008). Affective pictures were matched on arousal. Six of these pictures (2 unpleasant, 2 neutral, 2 pleasant) were chosen randomly and displayed 10 times each during a familiarization block. Following familiarization, participants completed 60 trials of passive picture-viewing (intermixed trials with half displaying familiar and half novel pictures) (see Baskin-Sommers et al., 2013 for details).

2.3. Psychophysiological recording and reduction

Stimulus presentation and data collection were controlled by a PC-based Matlab script (Brainard, 1997; Pelli, 1997) and Neuroscan Synamps amplifiers and acquisition software. Offline processing was conducted using EEGLab (Delorme & Makeig, 2004).

EEG was recorded from Ag–AgCl electrodes mounted in an elastic cap and located at standard midline positions referenced to the left mastoid. Vertical eye-movement was measured with electrodes placed above and below the left eye. Electrode impedance was kept below 10 KΩ. Offline processing included re-referencing to average mastoids, low pass filtering (2nd order, 30 Hz Butterworth low pass filter), epoching (−500 ms to 1000 ms epochs surrounding picture onset), baseline correction, artifact rejection (±75 μV).

Time frequency analyses focused on theta (4–8 Hz) at Pz. Changes in ITC were extracted using the EEGLab 'newtimef' function. Three-second epochs (at three cycles) were convolved using Morlet wavelets to yield Time x Frequency spectrograms for each of the experimental conditions (Fig. 1). Following visual inspection of the spectrograms, mean ITCs were extracted from the pre-computed matrices between 100 and 300 ms for the theta frequency band. Fisher r-to-z transformations were performed on the ITC data prior to all statistical analyses.

[1] For time-frequency analysis, power analyses generally examine the magnitude or strength of processing, whereas coherence methods measure readiness and integration aspects of processing. For the present study, the latter method aligns with the bottleneck model, which suggests psychopathic individuals fail to "answer the call for processing" because they have not integrating all of the components of the stimuli/environment.

3. Results

3.1. Psychopathy

Data were examined in a 2 (familiar, novel) by 3 (pleasant, neutral, unpleasant) General Linear Model (GLM) with PCL-R (z-score) as a continuous factor. Interaction contrasts were used to examine valence (unpleasant vs. pleasant) and affect (unpleasant/pleasant vs. neutral) effects.

Consistent with prior research, there was a significant familiarity main effect, $F(1,97) = 4.71$, $p = 0.032$, $\eta p^2 = 0.046$, with familiar pictures eliciting greater theta phase coherence than novel pictures. There were no significant main effects of emotion ($p = 0.435$), psychopathy ($p = 0.386$), nor two-way interactions.

There was a significant Familiarity x Valence x Psychopathy interaction, $F(1,97) = 7.69$, $p = 0.007$, $\eta p^2 = 0.073$. Psychopathic offenders displayed descriptively less coherent theta response to unpleasant versus pleasant novel pictures (B = −0.038, $p = 0.111$), but significantly more theta coherence to unpleasant versus pleasant familiar pictures (B = 0.048, $p = 0.042$) (Fig. 2).

3.2. Psychopathy factors

Some researchers have advocated parsing psychopathy into two component factors (Factor1: Interpersonal/Affective; Factor2: Impulsive/Antisocial) so that any unique correlates of these factors may be identified (Patrick, 2007). PCL-R Factor1 and Factor2 were entered simultaneously (z-score) into a GLM. There was a significant Familiarity x Valence x Factor1 interaction, $F(1,91) = 6.29$, $p = 0.014$, $\eta p^2 = 0.065$, where offenders high on Factor1 displayed significantly higher theta coherence during unpleasant versus pleasant familiar pictures (B = 0.067, $p = 0.010$), but not during novel pictures (B = −0.016, $p = 0.538$). In contrast, for Factor2, there was a significant Familiarity x Affect x Factor2 interaction, $F(1,91) = 4.92$, $p = 0.029$, $\eta p^2 = 0.051$, where offenders high on Factor2 displayed descriptively more theta coherence to affective (pleasant and unpleasant) compared to neutral pictures during novel trials (B = 0.042, $p = 0.061$), but not familiar ones (B = −0.034, $p = 0.163$).

4. Discussion

The present study used time-frequency analysis to examine whether sensory processing and integration affects the core affective deficits characteristic of psychopathy. Psychopathic offenders, and offenders high on Factor1, showed enhanced emotion-modulation of theta ITC to familiar, but not novel pictures. In contrast, theta coherence for offenders high on Factor2 was greater for both types of affective novel stimuli. These results suggest that the psychopathy and Factor-related dysregulation in processing affective information may stem from problems in the coherence of sensory and perceptual processing, albeit in different ways.

The majority of research on the psychopathy-related attention abnormalities uses instructional, top-down, sets to show that an attention bottleneck limits the allocation of resources when processing complex information (Hoppenbrouwers, Van der Stigchel, Slotboom, Dalmaijer, & Theeuwes, 2015; Larson et al., 2013). The present data suggest that this bottleneck may also inhibit lower level sensory perception of stimuli (Tombu et al., 2011). During novel pictures, psychopathic offenders (and Factor1) showed less emotion-modulation of theta phase coherence, suggesting that under high perceptual load, these individuals display dysfunction in their readiness to perceive and integrate information. However, when load was minimized during familiar pictures, offenders high on psychopathy displayed enhanced emotion-modulation of

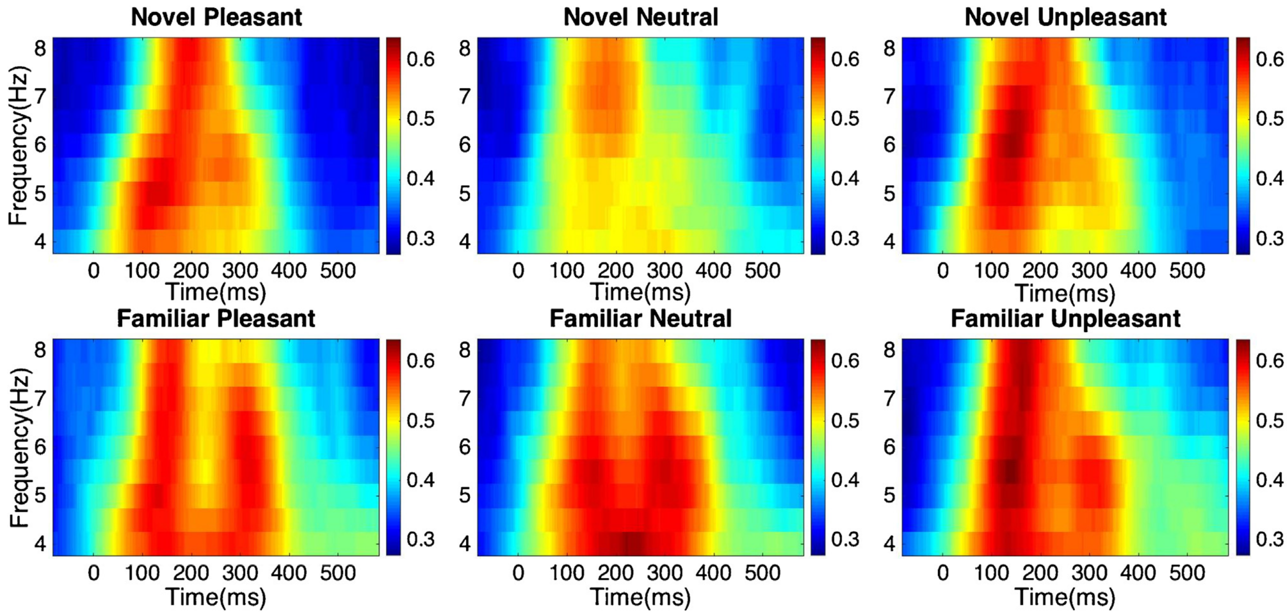

Fig. 1. Time-frequency spectrograms show changes in inter-trial coherence (ITC) following the presentation of novel pleasant, neutral, and unpleasant pictures (top row), and familiar pleasant, neutral, and unpleasant pictures (bottom row) during a passive picture-viewing task. Mean ITC data used for comparison was extracted from the 100–300 ms time window.

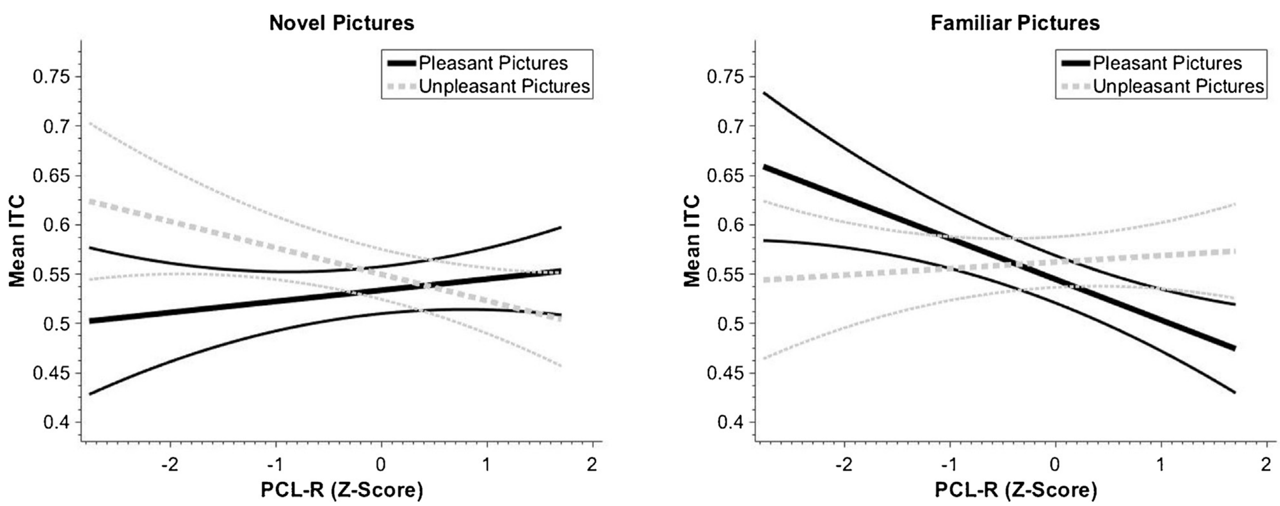

Fig. 2. Theta response as a function of psychopathy. Results for novel trials (left) show that as psychopathy increases, the valence contrast of the theta response (i.e. unpleasant vs pleasant) decreases ($B = -0.038$, $p = 0.111$), but during familiar trials (right) as psychopathy increases, the valence contrast of the theta response increases ($B = 0.048$, $p = 0.042$). Error bands are set at 1 standard error.

theta phase coherence. Given the consistency with the emotion-modulated startle findings, it is possible that the startle deficits in novel pictures may be due, in part, to a diminished readiness to perceive and integrate sensory information from multiple streams (e.g., visual processing of the picture and auditory processing of the startle probe). Moreover, the increased theta coherence during familiar pictures is consistent with work showing that psychopathic offenders over-respond to affective information when emotion is central to their goal or the demands of processing are alleviated (Flor, Birbaumer, Hermann, Ziegler, & Patrick, 2002; Newman et al., 2010). This diminished readiness to perceive and integrate affective information may result in poor neural detection and integration of sensory inputs across modalities and contribute to disruption of other neural processes that normally inhibit and regulate responses (Moul, Killcross, & Dadds, 2012).

Unlike the effects for psychopathy or Factor1, offenders high on Factor2 showed enhanced theta coherence to novel affective pictures, but a habituated response to affect during familiar pictures (see Hidalgo-Munoz et al., 2014). Factor2 traits are associated with heightened reward sensitivity and affective reactivity (Buckholtz et al., 2010). It is possible that offenders high on Factor2 are characterized by an underlying neurobiological vulnerability whereby they reflexively attend to and amplify affective information, ultimately leading to dysregulated responses to reward, threat, and emotionally-laden information (Baskin-Sommers & Newman, 2014). Though perception and integration may be dysfunctional in both psychopathy/Factor1 and Factor2 traits, the underlying sensitivities appear distinct, with the former relating more to load-based differences in processing valence and the latter relating more to elevated affective salience.

Combined with previous research, the present study provides evidence that, for psychopathic offenders, their impairment in evaluating and sorting sensory information leads to a disjointed perception of information and degraded representation of affective information. This failure in sensory processing may be central to understanding the underlying mechanisms responsible for the fractionated affective responses associated with psychopathy.

Acknowledgement

This work was supported by grant 5R21DA030876 from NIDA.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.biopsycho.2016.06.011.

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