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Research paper

Behavioral observations of positive and negative valence systems in early childhood predict physiological measures of emotional processing three years later

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ABSTRACT

Background: The Research Domain Criteria (RDoC) constructs of Positive Valence Systems (PVS) and Negative Valence Systems (NVS) are presumed to manifest behaviorally through early-emerging temperamental negative affectivity (NA) and positive affectivity (PA). The late positive potential (LPP) is a physiological measure of attention towards both negative and positive emotional stimuli; however, its associations with behavioral aspects of PVS and NVS have yet to be examined.
Methods: In a community sample of children ($N = 340$), we examined longitudinal relationships between observational measures of temperamental PA and NA assessed at age 6, and the LPP to both pleasant and unpleasant images assessed at age 9.
Results: Lower PA at age 6 predicted reduced LPP amplitudes to pleasant, but not unpleasant, images. NA as a composite measure was not related to the LPP, but specific associations were observed with facets of NA: greater fear predicted an enhanced LPP to unpleasant images, whereas greater sadness predicted a reduced LPP to unpleasant images.
Limitations: We were unable to evaluate concurrent associations between behavioral observations of temperament and the LPP, and effect sizes were modest.
Conclusions: Results support correspondence between behavioral and physiological measures of emotional processing across development, and provide evidence of discriminant validity in that PA was specifically related to the LPP to pleasant images, while facets of NA were specifically linked to the LPP to unpleasant images. Distinct associations of temperamental sadness and fear with the LPP highlight the importance of further evaluating subconstructs of NVS.

1. Introduction

The National Institute of Mental Health's Research Domain Criteria (RDoC) initiative aims to elucidate the mechanisms underlying psychopathology by focusing on core biobehavioral constructs that are dimensionally distributed and cut across traditional diagnostic boundaries. A key goal of RDoC is to elaborate the biological mechanisms associated with psychological processes by establishing linkages across multiple units of analysis—including brain circuits, physiology, self-report and behavior—in order to develop nomological nets around these constructs (Kozak and Cuthbert, 2016; Sanislow et al., 2010). An important aspect of establishing the validity of these constructs is to determine whether measures of each construct at different units of analysis are related to one another (i.e., convergent validity), and to establish discriminant validity in that units of analysis of one construct should not be related to other constructs (Kozak and Cuthbert, 2016; Shankman and Gorka, 2016).

The RDoC constructs of Negative Valence Systems (NVS) and Positive Valence Systems (PVS) stem from research on temperament, biobehavioral motivational systems, and psychopathology (Clark, 2005; Davidson, 1992; Gray, 1994; Kozak and Cuthbert, 2016; Lang et al., 1990). NVS include responses to acute and sustained threat,

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potential harm, frustrative nonreward, and loss, while PVS include approach motivation, initial and sustained responsiveness to reward, reward learning, and habit (Kozak and Cuthbert, 2016; National Institute of Mental Health, 2016). NVS and PVS have been linked to internalizing and externalizing psychopathology at the behavioral, physiological, and circuit levels of analysis. For example, some forms of depression are characterized by lower activation in PVS, including reduced expression of positive emotions (De Pauw and Mervielde, 2010; Klein et al., 2012; Kotov et al., 2010) and blunted reward responsiveness (Forbes and Dahl, 2012; Pizzagalli, 2014; Proudfit et al., 2015). On the other hand, externalizing symptoms, particularly hyperactivity and impulsivity, have been linked to increased activation in PVS (Tackett et al., 2012). NVS are consistently related to all forms of psychopathology (Tackett et al., 2013), but have the strongest association with symptoms of depression and anxiety, which are characterized by greater behavioral expression of negative emotions (De Pauw and Mervielde, 2010; Klein et al., 2012; Kotov et al., 2010), as well as altered neural processing of negative or threatening stimuli (Goodkind et al., 2013; Proudfit et al., 2015; Swartz and Monk, 2014). Importantly, there is growing evidence that abnormalities in these systems are observable among children at risk for internalizing disorders, prior to the onset of symptoms (Klein et al., 2012; Pine, 2007; Proudfit et al., 2015); thus RDoC constructs of PVS and NVS may inform our understanding of developmental pathways to psychopathology (Casey et al., 2014; Franklin et al., 2015; Shankman and Gorka, 2016).

At the behavioral level, temperament style is particularly relevant to PVS and NVS (Kozak and Cuthbert, 2016; National Institute of Mental Health, 2016). Temperament refers to individual differences in emotional reactivity, expression, and regulation that develop early in life, with strong genetic and biological bases, and substantial stability over time (Caspi and Shiner, 2006; Clark and Watson, 1999; Rothbart and Bates, 2006). Positive affectivity (PA), which includes expression of joy and exuberance, and negative affectivity (NA), which includes sadness, anger, and fear, are two aspects of temperament that are closely related to RDoC's PVS and NVS, respectively (Kozak and Cuthbert, 2016; National Institute of Mental Health, 2016), and can be measured at both the self-report and behavioral levels of analysis. As individual differences in NA and PA emerge early in life, they may be particularly useful units of analysis for informing the developmental origins of these RDoC constructs.

At the physiological level, the late positive potential (LPP) is an event-related potential (ERP) component that provides a neural measure of sustained attention towards motivationally salient stimuli, including positive and negative emotional faces, words, and scenes, and can be reliably and easily assessed in children and across development (Cuthbert et al., 2000; Hajcak et al., 2011; Kujawa et al., 2013; Schupp et al., 2006). A range of psychopathologies, including both anxiety and depression, have been characterized by an altered LPP to emotional stimuli (e.g., Foti et al., 2010; Kujawa et al., 2015a; MacNamara et al., 2015; Moser et al., 2008), suggesting it may be useful as a transdiagnostic measure of emotional processing. Through source localization and combining functional magnetic resonance imaging (fMRI) with ERP measures, the LPP has been linked to an extensive brain network, including visual cortex and coupling between occipitoparietal and frontal cortex, as well as activation in subcortical regions (Keil et al., 2002; Liu et al., 2012; Moratti et al., 2011; Sabatinelli et al., 2013, 2007).[2] Though the LPP is modulated by arousal (Olofsson et al., 2008) and similar brain regions appear to contribute to the LPP to both positive and negative stimuli, there is also evidence of somewhat distinct neural contributions depending on valence. For example, while activation in nucleus accumbens and medial prefrontal cortex (PFC) correlated with the LPP to pleasant images, activation in ventrolateral PFC and insula correlated with the LPP to unpleasant images (Liu et al., 2012).

Despite the need for a neurodevelopmental perspective to inform RDoC and evidence that individual differences in trait emotionality develop early in life, very little work has examined the relationships between observed behavior and physiology or circuits involved in PVS and NVS, an essential step for informing how individual differences in neural measures may relate to real-world functioning and behavior. Most of the developmental literature has focused on behavioral inhibition (BI), a temperament trait specifically characterized by fearfulness and withdrawal in novel situations (Kagan et al., 1987). For example, high BI in early childhood predicts greater right frontal electroencephalogram (EEG) asymmetry, enhanced ERP measures of error monitoring, and greater striatal activation during reward anticipation later in life (Bar-Haim et al., 2009; Fox et al., 2005; Guyer et al., 2006; McDermott et al., 2009).

In addition, we previously reported that lower PA in early childhood predicted a reduced reward positivity, an ERP component sensitive to receipt of reward, in middle to late childhood (Kujawa et al., 2015b). This finding provided evidence of correspondence between behavioral and physiological aspects of PVS, and also indicated discriminant validity in that NA was not related to physiological measures of reward processing. As the LPP is modulated by arousal during the processing of both positive and negative emotional information (Cuthbert et al., 2000; Hajcak et al., 2011; Olofsson et al., 2008), it may provide insight into distinct patterns of associations between behavioral expressions of PA and NA and physiological measures of emotional processing.

Consistent with this, two cross-sectional studies in youth have linked individual differences in the LPP to behavioral and questionnaire measures of NVS and PVS. In a sample of young children, observed fearful behavior was associated with an enhanced LPP specifically to unpleasant images in childhood (Solomon et al., 2012). More recently, in a large sample of adolescent girls, questionnaire measures of PA correlated with an enhanced LPP to both pleasant and unpleasant images, raising the possibility that greater PA corresponds to increased arousal during broad emotion processing (Speed et al., 2015). Compared to questionnaire measures, laboratory assessment of temperament provides an objective, micro-level examination of affective and behavioral responses (Goldsmith and Gagne, 2012); however, no previous studies have examined behavioral indicators of both NVS and PVS in relation to the LPP. In addition, as temperament develops early in life, examining the relationship between early-emerging temperament and the LPP later in life provides a particularly stringent test of the relationship between behavioral and physiological units of analysis.

The current study took a developmental approach to testing the convergent and discriminant validity of behavioral and physiological measures of emotional reactivity and processing. Specifically, at age 6, children completed an observational laboratory assessment of PA and NA. Approximately three years later, children completed an EEG assessment in which the LPP was recorded in response to both unpleasant and pleasant images. We tested whether behavioral measures of NVS and PVS predicted physiological measures of emotional processing three years later by examining observational measures of PA and NA at age 6 as predictors of the LPP to emotional images at age 9. As facets of NA (i.e., fear, sadness, anger) may relate to specific components of NVS (e.g., threat, loss, frustrative non-reward) and show distinct associations with physiological measures, we also examined fear, anger and sadness as predictors of the LPP at age 9. Consistent with prior work (Solomon et al., 2012; Speed et al., 2015), we hypothesized that greater PA would predict an enhanced LPP to pleasant images or to emotional images more broadly and greater fearfulness would predict an enhanced LPP to unpleasant images. Given evidence that fearfulness and anger are distinct with

[2] We refer to the LPP as a physiological measure, consistent with the placement of other ERP measures in the current RDoC Matrix (National Institute of Mental Health, 2016); however, it could also fit within the circuits level of analysis, as several studies have evaluated its relationship with specific brain regions.