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Future research directions in the Positive Valence Systems: Measurement, development, and implications for youth unipolar depression

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Abstract

The Positive Valence Systems (PVS) have been introduced by the National Institute of Mental Health as a domain to help organize multiple constructs focusing on reward seeking behaviors. However, the initial working model for this domain is strongly influenced by adult constructs and measures. Thus, the present review focuses on extending the PVS into a developmental context. Specifically, the review provides some hypotheses about the structure of the PVS, how PVS components may change throughout development, how family history of depression may influence PVS development, and potential means of intervening on PVS function to reduce onsets of depression. Future research needs in each of these areas are highlighted.

Keywords

reward; childhood; adolescence; development

There is a current emphasis on understanding how basic processes may transform our understanding of the commonalities and the distinctions between psychiatric illnesses and how these novel insights may be transformative for improving our interventions for these disorders (Cuthbert & Insel, 2013; Sanislow et al., 2010). In the past twenty years, several studies have investigated these commonalities using latent variable approaches to organize the structure of psychopathology. These studies have historically revealed a structure of correlated internalizing and externalizing disorder factors (Krueger, 1999; Krueger & Markon, 2006; Lahey et al., 2004; Slade & Watson, 2006). Yet, more recently, evidence from a number of studies is suggesting a common factor and domain specific factors across development (Caspi et al., 2014; Lahey et al., 2012; Lahey, Van Hulle, Singh, Waldman, & Rathouz, 2011; Olino, Dougherty, Bufferd, Carlson, & Klein, 2014). Although these studies highlight how an array of disorders belongs to the same factors, they do not identify which qualities are shared between disorders.

An alternative research strategy has been proposed by the National Institute of Mental Health through the Research Domain Criteria (RDoC) initiative. This initiative conceptualizes psychiatric illnesses as the result of disrupted functioning in a number of

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domains, including the Negative Valence Systems, Positive Valence Systems, Cognitive Systems, Systems for Social Processes, and Arousal/Regulatory Systems. Each of these systems is defined as a domain with multiple constructs. As attention to all constructs and domains could fill volumes, this paper will focus on the Positive Valence Systems (PVS). The purpose of this paper is to extend the PVS into a developmental context (and serve as a template for thinking about developmental extensions of other RDoC domains). Attention is paid to measurement of PVS constructs in youth populations and I highlight the influence of development on PVS functioning. As not all PVS constructs have been extensively investigated in youth, information about both adults and youth are presented throughout. I articulate potential structural models to organize PVS function, which is necessary for advancing work in translational neuroscience. Further, I will provide a framework linking atypical development of PVS functioning to depressive disorders in conjunction with other known risk factors, most prominently family history of depressive disorders. In particular, I posit that youth at particularly high risk for depression are those who demonstrate attenuated increases in levels of PVS function throughout adolescence and who have a parents with a history of depression. Finally, I will also link understanding the structure and development of PVS to potential prevention and intervention strategies.

PVS Organization and Structure

In the initial draft form, the PVS is a broad domain that is described as the set of systems that underlies engagement in positive environmental situations and contexts that includes five expert consensus constructs (PVS Work Group, 2011). These are not considered final and require additional empirical data to refine. However, I describe these constructs here to be consistent with the initial starting point. Approach motivation is comprised of four sub-constructs: reward valuation, willingness to work (given costs to achieve a reinforcer), expectancy of reward, and preference based decision making. Together, the broad construct involves the regulation of behaviors that result in reward achievement. Initial responsiveness to reward attainment involves hedonic responses during consummation of rewards. Sustained responsiveness to reward attainment involves cues of completion of reward pursuit and satiety of rewards. Reward learning involves linking information about stimuli and contexts with positive outcomes. Finally, habit is also included in the PVS, but is not emphasized here as links with depressive disorders may be less direct (although these may be particularly important for obsessive compulsive disorder and substance use disorders; Gerdeman, Partridge, Lupica, & Lovinger, 2003; Graybiel, 2008). Thus, the PVS reflects conceptually coherent processes: identification and engagement in behaviors that lead toward the achievement and satisfaction from rewards. As the initial description of the PVS emphasizes adults, construct examples for adults are presented first and then extended to youth.

One of the guiding principles of the RDoC is that unique information may be provided from different units of analysis. Thus, there are roles of genes, molecules, cells, circuits, physiology, behavior, self-report, and experimental paradigms highlighted for each construct and component processes for each domain and construct. There are several common processes involved at different units of analysis across PVS constructs. Dopaminergic function is highlighted as a key component of multiple processes both as a cell signaling molecule and genetic variants in dopamine receptors. The mesolimbic pathway, including the ventral striatum (in particular the nucleus accumbens) and dorsal striatum, are involved in nearly all PVS processes. Thus, dopaminergic transmission and neurons enervated by dopamine pathways are crucial for the PVS (Haber & Knutson, 2010; Knutson & Wimmer, 2007; Nestler & Carlezon, 2006) and are implicated in all of the PVS constructs. Although dopamine is involved in multiple PVS processes, several other neurotransmitters are implicated in specific constructs. Recent reviews describe molecular processes clearly (Bogdan, Nikolova, & Pizzagalli, 2013; Der-Avakian & Markou, 2012; Russo & Nestler, 2013). In these reviews, the authors provide evidence for the roles of additional genes and molecules, including those responsible for dopamine transporters and enzyme activity, endocannabinoids, and brain derived neurotrophic factor, in anticipation and response to receiving rewards and approach motivation. There is emerging work on how all of these molecular processes are involved in reward. Further, as there are noted developmental changes in reward function with development, it is important to consider possible epigenetic effects of pubertal hormones on reward function (Lombardo et al., 2012). Future work will provide valuable information about the roles of these molecules in specific PVS function. Beyond the striatum, there are several key neuroanatomical regions implicated in PVS functioning: the orbitofrontal cortex is involved in reward evaluation; the dorsal anterior cingulate cortex is involved in evaluating the effort necessary to gain a reward; and the ventromedial and dorsolateral prefrontal cortex are involved in decision making concerning effort and value assessments (Der-Avakian & Markou, 2012; Montague, King-Casas, & Cohen, 2006).

The PVS also includes psychological and behavioral phenomena as indices of the domain constructs. In particular, there are many self-report measures that inform the PVS functioning. The two traditions are most strongly represented in the PVS come from the psychiatric/clinical psychology and psychophysiological perspectives. Psychiatry and clinical psychology identified anhedonia as a critical symptom and individual difference characteristic for psychotic and depressive illnesses (Blanchard, 1998; Chapman, Chapman, & Raulin, 1976; Davidson, 1998; Fawcett, Clark, Scheftner, & Gibbons, 1983; Gard, Gard, Kring, & John, 2006; Kazdin, 1989; Meehl, 1975, 2001; Snaith et al., 1995; Watson et al., 1995). Anhedonia includes elements of multiple PVS constructs, including hedonic tone (Chapman et al., 1976; Kazdin, 1989; Watson et al., 1995), the capacity to experience pleasure (Fawcett et al., 1983; Snaith et al., 1995), and the temporal relationship to reward, with distinctions made between deficits in anticipation or during the receipt (i.e., consummatory phase) of rewards (Davidson, 1998; Gard et al., 2006). Anhedonia has also been divided by class of reward emphasizing social and physical domains (Chapman et al., 1976). Thus, multiple sub-dimensions of anhedonia assess specific PVS component processes.

From a psychophysiological perspective on personality, Gray (Gray, 1970, 1972) introduced the behavioral activation system (BAS) as a mechanism to explain approach behaviors and motivation (we do not discuss the role of the behavioral inhibition system; however, these processes are argued to work dynamically). The function of these systems has been largely (but not exclusively) operationalized using two self-report measures. The Behavioral Inhibition and Behavioral Activation scales (BIS-BAS; Carver & White, 1994) provides a total BAS score and three subscale scores of fun seeking, drive, and reward responsivity. These measures are hypothesized to map on to valuation of rewards, approach motivation, and longer-term responsiveness domains of the PVS constructs, respectively. In contrast, the Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ; Torrubia, Avila, Moltó, & Caseras, 2001) provides a single total score indexing reward valuation. Thus, there is coherence in the goal of the BAS and Sensitivity to Reward scales to assess individual differences in reward motivation. Additional specific measures may be used to assess specific PVS features with respect to eating behaviors (Hohlstein, Smith, & Atlas, 1998) and drug use (Morean et al., 2013).

Multiple behavioral tasks have been used to enhance our understanding of reward seeking behaviors. These tasks have been developed from different research perspectives and, consequently, provide information about different specific PVS construct processes. Some of the more commonly used behavioral tasks are the Delay Discounting Task (e.g., Steinberg et al., 2009), Effort Expenditure for Rewards Task (Treadway, Bossaller, Shelton, & Zald, 2012; Treadway, Buckholtz, Schwartzman, Lambert, & Zald, 2009), Iowa Gambling Task (Bechara, Damasio, Damasio, & Anderson, 1994), probabilistic learning task (e.g., signal detection task; Pizzagalli, Jahn, & O'Shea, 2005). These are elegant tasks that provide indices of reward valuation, willingness to work, and preference based decision making, and reward learning, respectively. However, few studies have administered these tasks within the same sample. Despite the tasks purporting to tap similar general processes, it is unclear if they demonstrate convergent validity.

Similar to the use of behavioral tasks, many tasks were designed to elicit PVS-relevant brain functioning using functional magnetic resonance imaging (fMRI), electroencephalogram (EEG), and event related potential (ERP) methods. Some behavioral tasks have been adapted to acquire neural data and others have been specifically designed for use for neural and psychophysiological probes. Resting-state frontal EEG asymmetry has historically been used to understand individual differences in approach-withdrawal tendencies, with left frontal activation reflecting greater approach behaviors (Davidson, Pizzagalli, Nitschke, & Putnam, 2002; Heller, Nitschke, Etienne, & Miller, 1997). However, the utility of this approach has been recently questioned (Davidson, 2004). More recently, task related EEG recordings have demonstrated utility. For example, Shankman et al. (2007) found that adults with early-onset depression had reduced left frontal EEG asymmetry relative to adults with late-onset depression and adults with no history of depression during the anticipation of rewards in a slot machine task. ERP studies of reward have often used simple binary guessing tasks to assess reward response (Dunning & Hajcak, 2007; Proudfit, 2014). The task reliably elicits an ERP response (feedback negativity) approximately 300 ms after feedback. Neural response in this task is correlated with ventral striatal response when assessed concurrently (Carlson, Foti, Mujica-Parodi, Harmon-Jones, & Hajcak, 2011). Thus, there is evidence for convergent validity of these measures.

Functional MRI studies of adults have often relied on the monetary incentive delay task to assess expectancy of reward and initial responsiveness to reward (Zhang, Chang, Guo, Zhang, & Wang, 2013). The monetary incentive delay (MID) task (Knutson, Adams, Fong, & Hommer, 2001; Knutson, Fong, Adams, Varner, & Hommer, 2001) relies on participants' own behavior (i.e., reaction time) to determine outcomes. The task often manipulates the potential trial earnings and costs on each trial and distinguishes between anticipation and receipt phases of rewards. The task reliably elicits ventral striatal activation and discriminates between individuals with and without depression (Dichter et al.; Pizzagalli, Iosifescu, Hallett, Ratner, & Fava, 2008; Simon et al., 2010; Smoski et al., 2009; Smoski, Rittenberg, & Dichter, 2011; Stoy et al., 2012). Reward based decision making often includes manipulating stimuli concerning the magnitude and probability of reward (Smoski et al., 2009). Results of work using both the MID and reward-based decision making find a rich network of neural response, particularly the ventral striatum (Monique Ernst et al., 2004; Smith et al., 2009).

The proposed PVS constructs were based on expert consensus in an initial attempt to describe multiple conceptually separable, but related processes. However, an empirically informed organizational structure of these elements is absent. Work on PVS structure would inform the distinctness of or overlap between the noted constructs. Surprisingly, there is little published data to inform the structure of these constructs, either within the same or across units of analysis, including studies relying solely on self-report PVS measures. Studies developing novel self-report instruments have presented correlation coefficients between the novel measure with historic measures to demonstrate convergent validity (e.g., Carver & White, 1994; Gard et al., 2006). However, these studies typically present incomplete correlation matrices focusing on their measure of interest, which prevents a full understanding of the inter-measure associations. There are few notable exceptions in the literature. Watson, Stasik, Ellickson-Larew, and Stanton (2015) examined the organization of lower-order facets of multiple measures of extraversion in a large sample of adults. Across these multiple measures, the authors identified four factors concerning the organization of the facets: positive emotion, sociability, assertiveness, and experience seeking. The positive emotion and experience seeking domains appear consistent with the PVS domains of responsiveness to reward and reward valuation. Watson et al. also identified two social orientation dimensions that are not included in the PVS organization. As the study included personality measures, but not explicit measures of narrow constructs, there was no expectation that the full complement of PVS constructs be identified. In a second study, Leventhal et al. (2006) examined the structure of anhedonia, in the context of anxiety and depressive symptoms, in undergraduate students. The authors found that found that multiple anhedonia measures loaded on the same latent factor, except for physical anhedonia. However, this study focused solely on anhedonia and did not attend to broader constructs within the PVS. Thus, these studies suggest that there may be multiple dimensions of PVS functioning.

In the absence of strong data, there are several plausible models that could describe the structure of the PVS. These models are described using the originally proposed domains from the PVS. However, additional critical tests of the structure of the proposed domains are necessary using the suggested and other measures of PVS function. It is quite plausible that empirically derived domains suggest a markedly different organization and labels for domains. Thus, analyses at the levels of domain and individual assessment are necessary to move forward.

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Consistent with the topography of the presented PVS a potential model to explain the structure of the constructs would include correlated factors, reflecting approach motivation (with sub-components), initial responsiveness to reward attainment, sustained responsiveness to reward, and reward learning (Figure 1, A). An appeal of this conceptualization is that there would be multiple components that might be (partially) distinct. This would be consistent with the description of the PVS as the Positive Valence *Systems* as opposed to a singular Positive Valence System. However, this model may be unsatisfying because it does not resolve theoretical predictions about the common genetic and neuroanatomical correlates of PVS functioning. As multiple constructs and domains are influenced by dopaminergic systems and ventral striatal circuits, two alternative models are plausible.

One alternative model suggests that PVS constructs are associated due the influence of a higher-order factor (Figure 1, B). That is, a single factor would influence the individual factors and those, in turn, would influence the observations of each domain. Here, again, all PVS constructs would be associated with each other, but an additional factor would explain the associations between the constructs. Thus, this model could be consistent with expected underlying genetics and functional neuroanatomy.

Finally, a second alternative model would include general and specific factors for the PVS constructs (Figure 1, C). Specifically, this model would include a general factor that would have direct influences on all measures of the PVS. In addition, the model would include specific factors that would have influences on subsets of measures of PVS, potentially mapping onto the distinct PVS constructs. This is a bifactor model (Yung, Thissen, & McLeod, 1999). This model is consistent with the general role of dopamine and ventral striatal systems in the entire PVS and includes the possibility of construct specificity in the functioning of the broader system. At the same time, this model includes distinct constructs for narrower functions. Identifying the optimal organization of the PVS will require testing these *a priori* potential models, as well as examining exploratory models.

Developmental Extensions of PVS

The previous section described the PVS as articulate in the RDoC and highlights possible domain structures. However, the basis of that discussion comes primarily from the adult literature. Thus, adapting the measures and constructs for use with youth is necessary. There are ability and behavioral differences that may compromise the validity of measures between youth and adults. For example, differences in cognitive ability that may render some tasks incomprehensible and have limited validity for youth. Tasks that require understanding of numeracy (e.g., outcome greater than a value yields a win) may be inappropriate for younger children. Questionnaire measures will require providing different contexts for or examples of behaviors for assessing the same target construct.

Investigators relying on neuroscience methods have adapted their work to study youth extensively. Reward tasks have been developed based on presentation of simple stimuli and feedback and tasks have been used in early childhood and elementary school ages (Bress, Smith, Foti, Klein, & Hajcak, 2012; Stavropoulos & Carver, 2014). These same reward tasks have been used in both ERP and fMRI studies that provide an opportunity to understand the same patterns of responsivity using multiple biological indices of reward. Further, as these tasks are easily understood by youth across a wide span of ages, these tasks can be used in cross-sectional and longitudinal studies to examine PVS development. Dunning and Hajcak (2007) developed a guessing task requiring participants to simply guess whether a reward is located behind one of two doors. Thus, the lack of task difficulty for this task makes this well suited for longitudinal work beginning in early childhood. Further, the FN elicited in this task demonstrates good convergent validity as it is associated with concurrent and earlier behavioral assessments of PE (Kujawa et al., 2015),. However, this task is typically administered without being able to discriminate between anticipation and receipt of rewards.

Similar monetary incentive guessing tasks have been developed to be used with youth using fMRI. One version of these tasks (Delgado, Nystrom, Fissell, Noll, & Fiez, 2000) relies on participants to guess whether a visually depicted card will be greater or less than a specified value with all task outcomes being predetermined. The task reliably elicits ventral striatal and medial prefrontal cortex reactivity (Bebko et al., 2014; Forbes, 2011; Forbes et al., 2009; Forbes, Ryan, et al., 2010; Hariri et al., 2006; Morgan, Shaw, & Forbes, 2014). This task was developed to permit making distinctions between neural response during the anticipation of rewards and during receipt of rewards. However, as the task requires some understanding of numeracy, younger participants may not be able to make the numerical comparisons to understand the task outcomes. Thus, alternative binary options that do not rely on numeracy may be necessary for younger participants.

Multiple tasks have been developed to assess narrow PVS processes. Reward based decision making has been examined using tasks with known probabilities of winning and reward magnitudes. For example, Forbes et al. (2006) examined the confluence of reward magnitude and probability in youth with depressive and anxiety disorders. Youth with depression demonstrated reduced striatal response across task conditions relative to unaffected youth. Thus, these tasks can provide both behavioral and neural indices of reward seeking behaviors, which are distinct from anticipation or receipt of rewards.

Similarly, a number of behavioral tasks have been developed specifically for or have been successfully adapted for use with younger populations. The delay discounting task has been extensively used to assess reward valuation, with respect to risky and immediate goals (Steinberg et al., 2009). The balloon analogue risk taking task (Lejuez, Aklin, Zvolensky, & Pedulla, 2003; Lejuez et al., 2002) has also been used with younger children with the same purpose (T. M. Morris, Hudson, & Dodd, 2014). Each of these tasks reflects youth impulsivity, which highlights the value of pursuing highly rewarding stimuli with little temporal delay.

A number of tasks have also been developed to assess increases in task engagement and willingness to work when there are additional incentives for improved speed and accuracy of task performance. For example, the card arranging reward responsivity objective test (CARROT; Al-Adawi, Powell, & Greenwood, 1998; Powell, Al-Adawi, Morgan, & Greenwood, 1996) assesses participants' baseline speed of card sorting and then provides incentives for sorting additional cards above their baseline total. Studies of willingness to work have a long tradition in animal models of reward pursuit and have been assessed using progressive ratio tasks (Killeen, Posadas-Sanchez, Johansen, & Thrailkill, 2009; Richardson & Roberts, 1996). These tasks rely on a constant reward value (e.g., same amount of food), but costs (e.g., lever or button presses) increases incrementally from one trial to the next. The key task outcome is when the animal ceases to pursue the reward because the effort necessary to earn the reward exceeds the value of the reward. In human adaptations, this approach has been used with alternative rewards, including nicotine for smokers (Rusted, Mackee, Williams, & Willner, 1998) and money with many populations. As this task is simple, there may be value in using this task with younger populations. Indeed, there is some evidence that this task is sensitive to development (Chelonis, Gravelin, & Paule, 2011). Other effort-based tasks developed for use with older adolescents and adults are of high interest to implement with youth (e.g., the Effort Expenditure for Rewards Task); however, they involve cognitive processing to balance probability and effort, which may be cognitively challenging for younger children. Thus, the utility of studying development with this task is not feasible.

Similarly, there have been some successful adaptations of reward expectancy and learning tasks. The Iowa Gambling Task (Bechara et al., 1994) has been successfully used in a number of youth studies and adapted to permit discriminate between reward seeking and loss avoidance (Cauffman et al., 2010). This task includes multiple decks that vary in their long-term probability of being a winning or losing deck. The key outcome is whether participants learn to select winning and avoid losing decks. Probabilistic reward learning tasks (Pizzagalli et al., 2005) have been implemented with the goal of inducing response biases towards a stimulus that is minimally distinguishable from another, but that is reinforced at a higher probability. Although developed for use with older adolescents and adults, performance on this task discriminated between youth with and without a history depressive and anxiety disorders (B. H. Morris, Bylsma, Yaroslavsky, Kovacs, & Rottenberg, 2015). Each of these tasks assess individuals’ propensity to seek rewards based on the probability of earning rewards. Although these tasks are all assessing similar constructs, there are no previous studies that have examined the patterns of performance across multiple PVS constructs. Some studies have examined multiple tasks of immediacy of reward, but this was limited to one construct.

There has been mixed attention to parent- and youth-self reports of PVS constructs. The BIS-BAS scales have been extensively used with adolescent populations (Cooper, Gomez, & Aucote, 2007; Yu, Branje, Keijsers, & Meeus, 2011) and downward extensions of these measures have been developed for use with children (Colder & O'connor, 2004; Coplan, Wilson, Frohlick, & Zelenski, 2006; Muris, Meesters, de Kanter, & Timmerman, 2005) and preschoolers (Blair, 2003). Similarly, measures of sensation seeking have been developed for youth (Steinberg et al., 2008). Thus, there is relatively good coverage of the reward valuation, effort valuation, and sustained responsiveness to reward constructs for youth self-reports. Youth reports of positive affect are also validly assessed across a variety of time frames using the PANAS (Ebesutani, Okamura, Higa-McMillan, & Chorpita, 2011; Laurent et al., 1999). Importantly, not all youth will be able to provide self-report measures; thus, many measures have companion parent report forms. Parent-child agreement is a controversial topic and full attention to this area would require a lengthy discussion. Thus, we refer readers to other sources for a full description of these key issues in the context of mental health, but the same concerns apply to PVS-relevant traits and behaviors (De Los Reyes et al., in press; De Los Reyes & Kazdin, 2005).

Despite an extensive history of interest in adults, there has been limited interest anhedonia in youth. Yet, this is a key component of assessing expectancy of, initial responsiveness to, and sustained response to reward within the PVS. Further, anhedonia is a symptom that presents similarly in preschoolers and older individuals with depression (Luby, 2010) and within a similar melancholic depression syndrome as it does in adults with depression (Luby, Mrakotsky, Heffelfinger, Brown, & Spitznagel, 2004). Anhedonia also holds important prognostic value as adolescents with higher levels of anhedonia have longer time until remission (McMakin et al., 2012). Thus, there is evidence for needing to more sensitively assess anhedonia in youth.

In the child literature, there is only one instrument that was developed to solely assess anhedonia. The Pleasure Scale for Children is a 39 item measure that demonstrated satisfactory psychometric properties and discriminated between depressed and non-depressed youth (Kazdin, 1989). However, the measure has garnered very little attention and been used sparingly in research. The measure assesses physical anhedonia and hedonic capacity with content similar to those used in traditional adult measures (Chapman et al., 1976; Fawcett et al., 1983; Snaith et al., 1995). Thus, we also know very little about the emergence of anhedonia with only one published study (Bennik, Nederhof, Ormel, & Oldehinkel, 2014) explicitly examining this issue. However, the generalizability of this work is questionable as the authors relied on a single item from the Youth Self-Report.

Although there is a dearth of measures that assess PVS constructs directly, temperament measures may provide an important window into PVS functioning in youth. Across major models of temperament and personality, PVS constructs are crucial (Ashton et al., 2004; Buss & Plomin, 1975, 1984; Digman, 1990; Eysenck, 1978; Goldberg, 1993; McCrae & Costa, 1987; Rothbart, Ahadi, Hershey, & Fisher, 2001; Rothbart & Derryberry, 1981; Shiner & Caspi, 2003; A. Thomas & Chess, 1977), particularly dimensions reflecting positive affect, engagement, and sustained interest (Depue & Collins, 1999; Lucas, Diener, Grob, Suh, & Shao, 2000; Olino, Klein, Durbin, Hayden, & Buckley, 2005; Tellegen, 1985; Watson & Clark, 1997; Whittle, Allen, Lubman, & Yücel, 2006). Thus, PE/E is an additional construct that may provide important information about for understanding PVS changes across development.

Temperament has been of interests to developmentalists and developmental psychopathologists for a long time (Goldsmith, Buss, Plomin, & Rothbart, 1987; Shiner et al., 2012). There are multiple models of temperament for which different temperament dimensions are emphasized (Goldsmith et al., 1987). However, for the PVS, the dimensions identified by Rothbart and colleagues (Capaldi & Rothbart, 1992; Garstein & Rothbart, 2003; Putnam, Gartstein, & Rothbart, 2006; Rothbart et al., 2001; Rothbart & Derryberry, 1981; Simonds, 2006) are most applicable. Rothbart has developed temperament measures for use with youth at different ages. Thus, as the developmental periods assessed differ, the corresponding items and scales included in the scales differ. However, across developmental periods and specific instruments, there are several key constructs assessed that are directly applicable to and fill the gaps that are left by other measures in assessing the PVS. Finally, although original Rothbart scales are described below, there may be alternative formulations of the items that better explain those data (Kotelnikova, Olino, Klein, Krysti, & Hayden, in press). However, these also may be useful for understanding PVS function.

Table 1 maps several of Rothbart's constructs across multiple developmentally adapted temperament measures on to the PVS based on scale content, rather than their historic labels. Within a temperament framework, high intensity pleasure reflects reward valuation, as each emphasizes the role of immediacy and high value rewards. Approach and positive anticipation both are related to expectancy of reward responses. In addition, smiling/laughter is a reflection of momentary affect in line with initial responsiveness to reward. Finally, pleasure sensitivity includes items that are similar in content (but developmentally appropriate) for assessing physical anhedonia that is captured in sustained responsiveness to reward. Very recently, Leventhal et al. (in press) found that the pleasure sensitivity scale was significantly associated with a commonly used measure of anhedonia (the Snaith-Hamilton Pleasure Scale) in a large sample of adolescents. The most provisional link between temperament dimensions and PVS functioning is for the attention and orienting Rothbart scales. These index purposive attention that one would demonstrate while engaging in tasks that result in reward. However, these behaviors may not be central to PVS per se and might be better captured by cognitive (attentional) systems.

Although there may be some imperfect mappings of temperament dimensions to PVS constructs, these are important links to examine. Further, these links would permit examinations of PVS functioning across a wider developmental span than would be possible if relying solely on youth self-report, behavioral performance, and indices of neural functioning. As these measures have not been conceptualized in this perspective previously, additional work is needed in demonstrating convergent validity between these dimensions of temperament and other measures of PVS function. This is most critical for studies examining constructs across different units of analysis.

Beyond self- and parent-report measures, novel assessments of PVS function may come from behavioral observations. The RDoC seeks to identify basic processes that give rise to psychopathological conditions. Thus, tensions may arise because observable behaviors involve many processes. From this perspective, it may be that unstructured laboratory or naturalistic observations may preclude direct mappings to PVS constructs. However, highly structured observational situations (akin to the Laboratory Temperament Assessment Battery; Goldsmith, Reilly, Lemery, Longley, & Prescott, 1995) may validly assess PVS functioning. For example, laboratory episodes are such that there are clear temporal markers of periods of anticipation of rewards where behavioral markers (e.g., smiling, positive verbalizations) will indicate expectancy of reward or behavioral displays will be present when rewards are obtained or earned (e.g., awaiting for cues to receive rewards and receiving rewards may be indexed by positive affect). Episodes are also constructed so that willingness to work towards earning rewards can be assessed. These are fruitful approaches that are novel the PVS framework, but could be capitalized on when youth reports may not be assessed directly. Indeed, there are emerging data supporting longitudinal validity of age three positive emotionality predicting reward responsiveness using ERP (i.e., FN) at age nine (Kujawa et al., 2015).

Furthermore, in addition to alternative measurement strategies, it is important to consider multiple reward modalities (Forbes, 2009; Forbes & Goodman, 2014; Kohls, Peltzer, Herpertz-Dahlmann, & Konrad, 2009). The majority of the incentives used in behavioral and neural probes for PVS functioning rely on money. There is some attention to primary drives, particularly food. As youth may have a different understanding of the value of money across development, Luking et al. (2014) examined the utility of candy as the reward in a study of children, adolescents, and adults. The results demonstrated that individuals from each developmental period showed similar levels of response.

In addition to money and food, social affiliative processes may be quite important for PVS functioning. The neural circuitry underlying social affiliation strongly overlaps with that of other incentives (Depue & Collins, 1999). Thus, the converse, social anhedonia may represent an important aspect of that broader construct. Recently, there has been interest expressed in mapping social anhedonia onto social interest and affiliation (Reise, Horan, & Blanchard, 2011), which reflect similar processes. Further, early childhood researchers have identified social disinterestedness as a construct pertinent to internalizing disorders (Coplan, Prakash, O'Neil, & Armer, 2004). Social disinterestedness reflects low motivation to seek out or engage with others; however, this construct does not include positive affective responses during the interaction. Nonetheless, social anhedonia and affiliation are additional elements of PVS functioning that warrant attention. In examinations of neural response to reward, some have considered the use of socially relevant positive stimuli (e.g., happy faces) as social rewards (Monk et al., 2008). However, there may be questions about the specific processes that underlie simple passive viewing. Currently a number of investigators have focused on providing faux peer feedback using fMRI (Davey, Allen, Harrison, Dwyer, & Yücel, 2010; Healey, Morgan, Musselman, Olino, & Forbes, 2014; Olino, Silk, Osterritter, & Forbes, in press; Silk et al., 2014) or ERP (Kujawa, Arfer, Klein, & Proudfit, 2014) methods. The pattern of neural responses demonstrated in these tasks is similar to that seen using monetary incentives. However, there are no available studies of youth that have examined whether there are associations between neural response to social and monetary incentives.

There has been much attention to developing measures of discrete PVS processes and examining how these are related to clinical and developmental outcomes. However, there has been much less attention to how these discrete processes are interrelated. Thus, like the literature with adults, there is little work done examining the structure of PVS constructs in youth. Olino et al. (2005) examined a narrower construct of positive emotionality, akin to adult extraversion, in preschool aged children using home and laboratory observation measures. In this study, positive mood, reward seeking, and social engagement were all strongly associated with a higher-order factor. There have been a number of recent reports on the broader structure of temperament that provide some attention to PVS structure. In a large study of preschoolers, Dyson et al. (2012) found that indicators of positive mood and reward seeking loaded on a shared factor, but there was a distinct factor for social interest. Kotelnokova et al. (2013) examined the structure of temperament in middle childhood. In this study, positive mood and social interest loaded on the same factor. Finally, Dyson et al. (in press) presented the structural stability of temperament by following up their analyses when the original sample was age 6. The best fitting model continued to include positive mood and reward seeking separate from social interest. However, there was a stronger association between these factors later in development ($r = .88$) than early in development ($r = .51$). Thus, initial evidence suggests that the structure of the PVS is quite stable based on observational methods. However, there appear to be some key changes with respect to how PVS constructs are associated with social interest from early to middle childhood. However, this work relies only on one level of analysis.

A comprehensive structural analysis of PVS function requires attending to strong method effects. Measures of self-reports, behavior, and indices of neural functioning should be much more strongly correlated within than across units of analysis. Thus, analyses addressing the structure of the PVS will require multiple measures at each unit of analysis to determine whether there is shared construct variance beyond common method variance. Some preliminary work has found promise for these types of models (Moser, Durbin, Patrick, & Schmidt, 2015; Patrick et al., 2013). However, it is critical that multiple assessments from each unit of analysis be available, such that the unit of analysis is not confounded with the construct of interest. Thus, ideally, multiple assessments of each construct are assessed at each unit of analysis. Importantly, the same structure is not necessary to be identified and may not make sense over the course of development. Identifying the organization of the PVS among youth will inform intervention and prevention strategies by delineating whether there may be a broad or multiple near-related targets for prevention (described later). Finally, although it is possible that the structural model of PVS will be the same for adults and youth, this is an open question. There are developmental changes in PVS function that may result in developmental differences in the structure of the broader construct.

Longitudinal Changes in PVS Functioning

Multiple components of the PVS demonstrate significant change through youth development, particularly for change in reward valuation throughout adolescence. The current literature includes mostly studies comparing participants coming from distinct developmental periods and only a small number of studies reporting on changes within participants. However, there has not been consistent attention to all PVS domains and longitudinal studies of PVS constructs have been rarely reported.

Although there are many studies reporting on associations between development, particularly relying on age, and PVS functioning, there are sparse available data on within-person changes in these individual difference characteristics, including PVS-relevant personality (Shiner & Caspi, 2003; Shiner & Masten, 2008). Much of this work has been summarized in a meta-analysis examining mean-level changes in personality across developmental periods (Roberts, Walton, & Viechtbauer, 2006). The study found that social vitality, including PA, sociability, and gregariousness, did not significantly increases from age 10 to 18. However, other PVS components reflecting social dominance and self-confidence did significantly increase from age 10 through 18. These results are based on only a small number of studies (12 and 5, respectively). Thus, there may have been relatively little power to detect changes in PA, sociability, and gregariousness. Further, with the small number of studies, tests of moderators of developmental change were unable to be conducted. However, these results are suggestive that constructs related to reward valuation (e.g., dominance) may be more strongly influenced by development than initial responsiveness to reward (e.g., PA).

Little data are available on developmental changes in anhedonia. Only one published study examined changes in anhedonia longitudinally in adolescence (Bennik et al., 2014). The authors found that the likelihood of endorsement of anhedonia decreased from age 11 to 19 across four assessments, suggesting that anhedonia normatively declines in this period. However, this finding was based on a single item. Similarly, there are surprisingly sparing data on BAS change over the course of adolescence. In the only studies to examine longitudinal changes in BAS, Urosevic et al. (2012) found that there were significant increases in BAS Reward Responsiveness over a two year period for early adolescents, but not for late adolescents or young adults. Further, changes in each cohort did not significantly increase for BAS Drive or Fun Seeking. Thus, these data suggest that sustained response to reward increases from early to middle adolescence. Despite the understanding that there are important changes in affective functioning in adolescence, this has not been paralleled by investigations of these changes, broadly.

In contrast to the literatures on change in personality and anhedonia, there is a robust literature focusing on changes in reward valuation across adolescence. These studies find that risk taking behaviors, characterized by pursuits of immediate rewards, peak in adolescence (Galvan, Hare, Voss, Glover, & Casey, 2007; Steinberg, 2004, 2007, 2008). This is demonstrated across methods, including adolescent self-reports and lab-based measures of impulsivity (Lee et al., 2013; Olson, Hooper, Collins, & Luciana, 2007; Steinberg et al., 2009). Behavioral measures of reward seeking also demonstrate similar patterns of change with children and adolescents earned more rewards on a PR task than younger children (Chelonis et al., 2011). Yet, most of this literature is based on cross-sectional studies, with only few longitudinal studies in this area. For example, Anokhin et al. (2011) found that impulsive decisions decreased from age 12 to 14 years. In a follow-up report, Anokhin et al. (2015) reported on longitudinal changed from age 16 to 18 and 18 to 20 and found decreased in impulsivity across these periods as well. This suggests decreases in delay discounting impulsivity across adolescence. However, using the Iowa Gambling Task, Tuvblad et al. (2013) reported that the number of risky decisions during the task were similar in early- and mid-adolescence (ages 11-16) and significantly higher than in older adolescence (ages 17-18). Thus, although there is general consensus in findings across the cross-sectional studies, the findings from the initial longitudinal studies are mixed.

Studies relying on other behavioral tasks assessing other forms of PVS are very rare. Very recently, Morris et al. (2015) examined reward learning in a reasonably large study of youth (n = 204; age range 8-19 years). They used a signal detection task that induces a response bias for preferential responding. However, in this sample, age was unrelated to the degree of bias induced in the task. Further work examining whether reward learning changes throughout development are needed.

A number of studies have conducted cross-sectional comparisons of children, adolescents, and adults on neural response to anticipation and/or receipt of monetary rewards using fMRI (Monique Ernst et al., 2005; Forbes, Ryan, et al., 2010; Galvan, 2013; Galvan et al., 2006; Geier, Terwilliger, Teslovich, Velanova, & Luna, 2010; Van Leijenhorst et al., 2010) and ERP (Crowley et al., 2013; Martínez-Velázquez, Ramos-Loyo, González-Garrido, & Sequeira, 2015; Zottoli & Grose-Fifer, 2012) methods. These studies largely (although conflicting results are present; Lukie, Montazer-Hojat, & Holroyd, 2014; Luking et al., 2014; Richards, Plate, & Ernst, 2012) find that adolescent neural response, particularly in the VS, is greater than that in children and adults. Conclusions from these studies suggest that adolescence is a period of significant development and reorganization of reward-related neurobiological circuits. Yet, as nearly all of this work is cross-sectional, important questions remain unanswered. For example, by conducting group comparisons, important heterogeneity is obfuscated within the age-based developmental groups. All individuals within a group are considered to be developmentally equivalent, even though there may be tremendous variability within the groups. Longitudinal studies provide a better opportunity to examine change more sensitively and identify, specifically, when in development these developmental processes begin to unfold.

Despite the strengths of longitudinal studies, we are aware of only two within-subject studies of PVS using probes of neural functioning. Importantly, these studies followed individuals from adolescence to young adulthood (Lamm et al., 2014; van Duijvenvoorde et al., 2014). Both studies found increased ventral striatal response with advancing age. However, both studies included small number of participants (*n*s = 23 and 33) and began after the onset of puberty. Thus, these studies cannot speak to whether pubertal development is associated with changes in PVS function in humans. It is crucial to study how transitioning into puberty is associated with developmental changes in PVS function. Thus, studies of younger samples are needed.

These developmental findings of PVS changes in neural response have relied extensively on monetary outcomes. An emerging literature finds that social context and social rewards are particularly potent in adolescence. However, there are few published studies that examine developmental differences across adolescence with respect to social rewards or acceptance. In one of the only published studies, Silk et al. (2014) did not find any significant associations between pubertal development and response to reward. This may have been due to examining this question in a mixed healthy and depressed adolescent sample. However, others have found that patterns of reward-related behavior changes depending on social context (O'Brien, Albert, Chein, & Steinberg, 2011). Thus, future work examining both whether there are changes in social reward responding across development and how social context alters reward responsiveness across modalities are of particular interest.

The immediately previous discussion focused on expected longitudinal changes in PVS functioning within specific constructs at different units of analysis. Overall, there are still only few studies that examine changes in PVS function throughout adolescence. Those that have been conducted have focused solely on a single measure as an outcome. Two critical questions have not yet garnered attention. First, is there uniformity in development of PVS constructs? Thus, is change in one domain associated with change in others, or do they follow distinct developmental trajectories? Second, does the structure of PVS constructs remain the same across development?

There is an expectation that with adolescent development, there will be increases in PVS function (M. Ernst & Fudge, 2009; Strang, Chein, & Steinberg, 2013). However, the support for this proposition is limited. First, there have been few longitudinal studies conducted that has examined this hypothesis. Those that have been conducted have examined longitudinal change beginning when youth were already adolescents. Thus, there is ambiguity about whether adolescent or pubertal development, specifically, is instigating the changes beginning in adolescence. Second, there may be heterogeneity in the patterns of increases or timing of increases. That is, some constructs may demonstrate increases in different amounts or may demonstrate increases at different times. Indeed, one recent study (Hoogendam, Kahn, Hillegers, van Buuren, & Vink, 2013) reported differences in developmental changes in neural response to reward anticipation and response to reward outcome within the same task. Thus, the possibility that there may be different patterns of development across related domains needs specific attention.

Beyond potential mean-level changes in PVS functioning, the relationships between constructs may also change. Thus, the structure of the PVS domain may change over time. However, there are few data to directly bear on the possibility that the relationships among PVS constructs may change over time. One hypothetical pattern of change may lead to expectations that the constructs may become more differentiated over time. That is, early in development, there may be a general approach tendency that is manifest, but over time nuance in these constructs would appear and become distinct. Thus, it could be that a one-factor may be present early in development. However, throughout development, constructs may become differentiated and the structure may be better defined based on one of the models proposed in Figure 1 or the number and labels for constructs identified may differ from those noted in the row headings of Figure 2. These developmental differences in structure may have important implications for prevention and intervention (discussed later).

PVS Functioning and Development and Course of Depression

PVS functioning has a prominent role in a number of forms of psychopathology, including schizophrenia (Strauss & Gold, 2012), bipolar disorder (Whitton, Treadway, & Pizzagalli, 2015), anorexia (Frank et al., 2012), and depression (Meehl, 1975, 2001). Thus, there are examples that can be drawn from the literature on each of these areas. Here, unipolar depression is emphasized, but parallel inquiries and developmental extensions outlined here can be applied to the other disorders.

In major depression, markedly diminished interest or pleasure is identified as a cardinal symptom of the disorder (APA, 2013). Thus, using PVS constructs, depression may include alterations in reward valuation and responsiveness to reward (both short- and long-term) as a primary symptom of the disorder. Attenuated PVS function is also revealed in related constructs. A recent meta-analysis reported that individuals with depression self-report lower levels of extraversion than individuals without depression (Kotov, Gamez, Schmidt, & Watson, 2010), with this finding being particularly evident for individuals with chronic depression (Wilson, DiRago, & Iacono, 2014). Adults (Pinto-Meza et al., 2006) and youth samples (Mellick, Sharp, & Alfano, 2014) find that individuals with a history of depression report lower levels of BAS than those without a history of depression. Unsurprisingly, youth with depression report higher levels of anhedonia that those without depression (Kazdin, 1989). In addition, in preschoolers, anhedonia also discriminated between those with depression versus anxiety and disruptive behavior disorders (Luby, Belden, Pautsch, Si, & Spitznagel, 2009).

Attenuated behavioral manifestations of PVS among individuals with depression are also reported in the literature, both in terms of implicit reward learning and willingness to work for rewards (B. H. Morris et al., 2015; Pizzagalli et al., 2008; Treadway et al., 2012). In an adult sample, Pizzagalli et al. (2008) found that adults with depression failed develop a bias towards preferentially reinforced stimuli relative to adults without depression. Similar results have been reported in a sample of children and adolescents with depression, social phobia, generalized anxiety disorder, and post-traumatic stress disorder (B. H. Morris et al., 2015). Using a paradigm assessing willingness to work in a sample of adults, Treadway et al. (2012) found that individual with depression were less likely to expend effort in order to obtain stronger rewards than those without depression. Similarly, adults (Cella, Dymond, & Cooper, 2010) and youth (Han et al., 2012) with depression do not modulate their behavior as strongly as those without depression during the Iowa Gambling Task to earn more money. Thus, there are multiple domains of PVS functioning that demonstrate cross-sectional differences between those with and without depressive disorders.

Finally, ERP and fMRI studies have found similar patterns of results. In one of the only ERP studies to examine individuals with depressive disorders, Liu et al. (2014) found reduced FN response during a simple gambling task for adults with depression relative to those without depression. Further, anhedonic symptom severity was significantly associated with FN among the individuals with depression. In contrast, there are multiple studies comparing depressed and non-depressed adults and youth using reward paradigms using fMRI (e.g., Chantiluke et al., 2012; Forbes et al., 2009; Knutson, Bhanji, Cooney, Atlas, & Gotlib, 2008; Pizzagalli et al., 2009; Smoski et al., 2009; Stoy et al., 2012). A recent meta-analysis of fMRI studies found lower ventral striatal and augmented medial prefrontal cortex response to reward in individuals with depression relative to individuals without depression inclusive of youth and adult samples (Zhang et al., 2013). Thus, there are a wide array of data finding that individuals and youth with depression have reduced PVS functioning relative to those without depression.

PVS functioning has demonstrated important information about prediction of course of depression, both in naturalistic follow-ups and in the context of treatment. Anhedonia in adolescence predicted the development of depressive disorders in adulthood (Pine, Cohen, Cohen, & Brook, 1999; Wilcox & Anthony, 2004). Higher self-reported levels of BAS functioning predict a more promising naturalistic course of depressive symptoms in adults with a history of MDD (Kasch, Rottenberg, Arnow, & Gotlib, 2002). Neural assessments of reward also have been associated with the development of depressive disorders and symptoms in short-term follow-up studies spanning one-year (Bress et al., 2012; Morgan, Olino, McMakin, Ryan, & Forbes, 2013). Most impressive, Bress et al. (2013) found that reduced FN predicted depression onset among adolescent girls through a one-year follow-up. Thus, across multiple methods, there is evidence that PVS influences longitudinal course of symptoms and disorder onset. However, the prediction of course of depressive symptoms or disorders has not been evaluated for all PVS constructs.

In the context of treatment, higher self-reported levels of anhedonia and positive affect predicted significantly longer times until remission for adolescents and adults (McMakin et al., 2012; Uher et al., 2012). Reward-related brain activity, indexed as striatal response to monetary rewards, also is associated with rate of change in negative affect over the course of treatment in depressed youth (Forbes, Olino, et al., 2010). The findings from these studies demonstrate that stronger PVS, across multiple levels of analysis, is longitudinally associated with attenuation of negative affective symptoms of and reduction of depression. Finally, although rarely considered in the broader literature, anhedonia has been demonstrated to be a marker of depression severity among preschool youth (Luby et al., 2004). The authors found that the presence of anhedonia was associated with increased familial risk for depression, altered cortisol reactivity, and greater depression severity. However, these data speak solely to alterations of PVS function once depression has onset. Additional work is required on factors that influence the manifestation of PVS functioning before the onset of depressive disorders.

Potential Key Factors Influencing PVS Functioning

Beyond development, there are a range of factors that have been demonstrated substantial implications for PVS function. Here, the focus is on parental history of depressive disorders, youth experience of stress, and youth experience of parenting.

In the present review, implications of PVS function are placed in the context of risk for depression. It is known that unipolar depression is etiologically heterogeneous (Goldstein & Klein, 2014; Goodman & Gotlib, 1999, 2002; Gotlib, Joormann, & Foland-Ross, 2014) and requires attention to multiple risk factors. Constructs within the PVS have been included within many models of risk, but have not often served a central role. As having a parent with a history of depression is one of the strongest and most consistent predictors of offspring depression (Goodman et al., 2011; C. Hammen & Brennan, 2003; Klein, Lewinsohn, Rohde, Seeley, & Olino, 2005; Lieb, Bronisch, Höfler, Schreier, & Wittchen, 2005), our discussion begins by providing a brief overview of the links between parental depression and youth PVS functioning.

Offspring designs have been very informative for understanding how PVS functioning is influenced by parental depression. Few published studies report on behavioral performance task differences between youth with and without a family history of depressive disorders. One recent report did not find associations between familial depression risk status and reward learning (B. H. Morris et al., 2015). In contrast, Mannie et al. found that adult offspring of depressed parents made significantly more risky decisions than offspring of non-depressed parents. However, an emerging number of recent studies find reduced PVS functioning is present in youth and young adults with a family, but not personal history, of depression in self-report (Bruder-Costello et al., 2007; Mufson, Nomura, & Warner, 2002), behavioral (Durbin, Klein, Hayden, Buckley, & Moerk, 2005; Goodman et al., 2011; Olino et al., 2011) and neuroimaging (Gotlib et al., 2010; McCabe, Woffindale, Harmer, & Cowen, 2012; Monk et al., 2008; Olino, McMakin, et al., 2014; Olino et al., in press; Sharp et al., 2014) studies. Impressively, the studies finding differences in positive affect are present in the preschool and school age years that are well before the peak period of risk (Durbin et al., 2005; Olino et al., 2011). Finally, the neuroimaging studies find that high-risk youth demonstrate attenuated ventral striatal response to monetary (Olino, McMakin, et al., 2014) and social (Olino et al., in press) rewards even when the youth do not differ on levels of depressive symptoms. These studies demonstrate that reduced reward responsiveness is present in never depressed offspring of depressed parents across multiple units of analysis and developmental periods in youth. However, the literature on resting state EEG is quite conflicted. A number of studies of infants of depressed mothers find greater right asymmetry (Field, Fox, Pickens, & Nawrocki, 1995; Jones, Field, & Davalos, 2000), which would suggest greater fear-based low approach (akin to the literature on behavioral inhibition; Rosenbaum et al., 2000)

Implicit in high-risk offspring studies is that these domains of function are influenced, at least in part, by genetics related to depression. Thus, these may reflect primary deficits in hedonic tone or the specific PVS constructs (Meehl, 2001). These would be consonant with conceptualizing attenuated PVS function as a temperamental disposition. Further, these may reflect intermediate phenotypes or endophenotypes (Gottesman & Gould, 2003; Hasler, Drevets, Manji, & Charney, 2004; Hasler & Northoff, 2011; Miller & Rockstroh, 2013). However, more evidence beyond one aspect of cosegregation is needed to support this claim. Based on the available evidence, these findings suggest that altered PVS function, broadly stated, may be a risk factor or, in some instances, a biomarker for depression (Lenzenweger, 2013). However, different constructs within the PVS may be revealed as endophenotypes, but not others.

In contrast, other models have been recently proposed to account for a secondary acquisition of PVS function disruptions that focus on experience of stress. Very recently, Pizzagalli (2014) comprehensively reviewed the literature linking exposure to stress and diminished experience of pleasure or anhedonia. The synthesis of results from both human and animal work provided a compelling case for the influence of stress on reward function, including dopamine signaling and tendencies to engage in approach behaviors. Here, support for this model is extended by discussing additional work on youth relying on subjective reports, neural activation, and social rewards.

In a sample of late adolescents/young adults, Bogdan and Pizzagalli (2006) examined the influence of threat of shock and negative feedback as stressors during the administration of a reward learning task. The authors found that the threat of shock condition resulted in reduced reward learning relative to when the task was completed without the threat of shock. In a naturalistic longitudinal study of adolescents, Wetter and Hankin (2009) found that the relationship between positive emotionality, conceptualized as a dimension of temperament, and anhedonic symptoms of depression was influenced by levels of interpersonal support. The authors found that supportive relationships both served as a moderator and mediator of the direct association between PE and anhedonic depression symptoms. Casement et al.

(2014) examined the longitudinal prediction of peer victimization at ages 11 and 12 to neural response to monetary incentives at age 16 in a large sample of girls. The authors found that higher levels of peer victimization were associated with reduced medial prefrontal cortex activation, but not other primary areas of reward related brain function. In a study examining multiple units of analysis, Nikolova et al. (2012) found that the relationship between experienced stress and self-reported positive affect differed across neural response to reward. Specifically, for individual with higher striatal response to rewards, there was a non-significant association between stress and positive affect; however, for individuals with lower striatal response to reward, there was a negative association between stress and PA. Across these studies, there is evidence for stress influencing PVS functioning directly and as a moderator of additional influences. Unfortunately, the current literature does not speak to the influence of the experience of acute stress and impacts on all constructs within the PVS and across all units of analysis.

The previously described studies of neural response to reward in the context of stress have relied on monetary incentives. However, it may be particularly important to attend to responses to social incentives, particularly during adolescence. A number of recent studies have examined the influence of the experience of stress, particularly conceptualized as peer victimization, and response to rejection using the cyberball task (Williams, Cheung, & Choi, 2000; Williams et al., 2002). Studies have reported that youth with higher levels of rejection sensitivity (Masten et al., 2009), who spent less time with their friends (Masten, Telzer, Fuligni, Lieberman, & Eisenberger, 2012), and who experienced chronic peer rejection (Will, van Lier, Crone, & Güroğlu, in press) demonstrated heightened neural response to rejection. A key limitation of the cyberball task is that typical administration does not include a task condition to assess response to acceptance, inclusion, or social rewards. There have been a number of tasks recently developed that provide the opportunity to examine response to both youth acceptance and rejection using fMRI (Davey et al., 2010; Guyer, McClure-Tone, Shiffrin, Pine, & Nelson, 2009; Healey et al., 2014; Silk et al., 2014) and ERP (Kujawa et al., 2014); however, studies examining the influence of stress or peer victimization and response to acceptance in these tasks have not been reported in the literature.

In studies of youth, there is much attention to the associations between parenting and offspring temperament (Karreman, van Tuijl, van Aken, & Deković, 2006; Paulussen-Hoogeboom, Stams, Hermanns, & Peetsma, 2007) and psychopathology (McLeod, Weisz, & Wood, 2007; McLeod, Wood, & Weisz, 2007). Yet, this work has predominantly focused on parenting practices in relation to youth negative emotionality and psychopathology. Yet, parenting practices are likely crucial for the development of positive emotional functioning. Yap, Allen, and Ladouceur (2008) reported that maternal behaviors that invalidated or dampened youth positive affect was associated with greater dysregulated behavior and depressive symptoms in youth. The results of this study are quite impressive as the study was conducted with an adolescent sample, whereas one may expect that these scaffolding behaviors among parents may be more central when youth are much younger. However, additional investigations of these mechanisms are needed with younger samples. Similarly, Katz et al. (2014) found that mothers and fathers of depressed youth were less accepting of and dampened youth positive affect to a greater extent than parents of non-depressed youth.

Thus, parenting that involves less support towards youth positive affect are present when either the parent or youth is depressed. In a study relying on neural indices of reward, Morgan, Shaw, and Forbes (2014) found that maternal warmth assessed in late childhood (ages 10-11) prospectively predicted greater mPFC response to winning, but less caudate response to losing money nearly ten years later. Finally, Whittle et al. (2009) examined the relationships among maternal responses to youth positive affect during observational tasks and neural structure in key reward regions, including the anterior cingulate cortex. The authors found that maternal behaviors that were not supportive of youth PA displays during a problem solving task were associated with greater dorsal anterior cingulate cortex volumes. Thus, parenting behaviors influence both brain function *and* structure, although in correlational studies, the directionality is unclear.

These particular studies emphasize normative variation in experiences of parenting. Other studies have emphasized more severe circumstances in parenting and early caregiving, including maltreatment and abuse. In one of the first studies of its kind, Guyer et al. (2006) examined reward-based decision making in youth with a history of maltreatment. The authors found that youth with a history of maltreatment selected riskier options more quickly and were less responsive to experimental context (i.e., probability of reward) than youth without a history of maltreatment. Dillon et al. (2009) compared adults with documented histories of maltreatment during childhood and individuals without such a history on a fMRI monetary incentive delay task. The authors found that the individuals with maltreatment histories had less basal ganglia response to reward cues than those without such a history. Interestingly, individuals with a history of maltreatment also demonstrated greater anhedonic symptoms. Studies of both normative parenting and more severe rearing circumstances are associated with attenuated response to reward. Across these areas examining family history, experience of stress, and experience of parenting, work is only emerging that addresses these influences on youth PVS function. Thus, it is unclear which elements of PVS functioning are sensitive to these influences.

Familial Risk for Depression Interplay with PVS *Development*

Collectively, the previously described work highlights differences between groups on and associations with PVS functioning based on single assessment occasions. However, PVS constructs should change with development. Thus, it is crucial to understand how known risk factors influence the developmental *changes* in PVS domains across youth development. Here, the emphasis is on unfolding the possibility that family history of depression may influence more than just a one-time assessment of PVS functioning. In addition, one extension of this model includes the dynamic influence of stress.

One potential framework for the transmission of depression across generations focuses on the possibility that parental depression influences youth depression indirectly through reduced reward function (see Figure 2 for the heuristic model). An important consideration in this model is whether reduced PVS function is thought of as a static or developmental (i.e., dynamic) characteristic. The previous literature of PVS function and risk for depression has largely considered reward-function as a static, trait-level characteristic (Bress et al., 2013; Bress et al., 2012; Gotlib et al., 2010; McCabe et al., 2012; Morgan et al., 2013;

Olino, McMakin, et al., 2014; Olino et al., in press). However, as described above, there are crucial developmental changes in these processes that are expected to begin in adolescence. Thus, beyond mean-level differences between offspring of depressed and non-depressed parents, a novel hypothesis is that youth of depressed parents will show dissimilar trajectories of PVS function across adolescence than youth of non-depressed parents. More precisely, the key expectation in this framework is that parental depression influences youth depression indirectly by *slowing the rate reward function development*. This model would also suggest that differences between youth at high- and low-risk for depression on PVS will be more modest earlier than later in development. Further, this model emphasizes group level differences in PVS both in terms of identification of risk markers and associations between risk markers and MDD. Finally, based on the literature on the experience of stress and less warm and/or harsh parenting, it is also possible that these experiences may lead to even greater impairments in PVS development. Critical tests of these possibilities may elucidate important relationships that may be targeted by prevention efforts.

An alternative framework that comes from this model posits that family history of depression and trajectory of PVS interact to predict onset of depressive disorders or increases in depressive symptoms (see Figures 3a and 3b for heuristic models). The emphasis here is on the individual differences in PVS trajectories. That is, do individual differences in PVS trajectories, specifically the rates of change, interact with family risk status to predict depression outcomes? As argued earlier, although there are group level differences observed between children and adolescents on measures of PVS functioning, there is important variability within each of these groups on PVS functioning and, presumably, how PVS function changes across time. I expect that group differences in PVS across youth at high- and low-risk for depression may reflect a gross level of risk for MDD (i.e., main effect differences for PVS functioning based on family history). However, the individual level in rate of change in PVS may modulate the degree of risk and reflect the level of risk for an individual. High-risk youth who demonstrate normative changes in PVS across adolescence would be anticipated to be *protected* from developing MDD and/or symptoms whereas high-risk youth who demonstrate attenuated increases in PVS would be at heightened risk for developing MDD and/or symptoms. Similar expectations would be present for youth at low familial risk, but these youth would be at lower risk overall than the youth of depressed parents. This pattern would suggest that normative developmental change serves as a protective factor, regardless of the initial levels of PVS. Thus, this perspective may be more powerful in describing individual levels of risk than the previously described model focusing on mediation, which focuses on aggregate group risk. Relative to the mediation model, I expect that there will be greater power to predict depression from the moderation model.

This general description requires many caveats. One crucial issue is about specificity of PVS function. There are multiple PVS constructs and there is much unknown about how each develops over adolescence and how each are influenced by family history of depression. Thus, much more empirical work is needed to identify which domains are most strongly implicated with risk.

In the context of development, an appealing hypothesis is that attenuated development of response to social, relative to monetary rewards will be centrally involved with risk for depression. Models of risk for depression have focused on social rewards as complex distal outcomes (Davey, Yucel, & Allen, 2008) or have focused on phenomena that give rise to gender differences in depression (Cyranowski, Frank, Young, & Shear, 2000; Hyde, Mezulis, & Abramson, 2008). In these models, the emphasis has been on the impact of continued rejection on social reward pursuit. That is, after multiple experiences of failure in social contexts, a sense of learned helplessness is generated towards social rewards. However, these models emphasize the learning history of continued rejection (i.e., secondary or acquired social motivation deficits), but do not frankly consider individual differences in motivation to pursue in social rewards. Some individuals are do not strongly responsive to social rewards, regardless of past history of acceptance or rejection. Thus, primary reward motivation differences (i.e., disposition-based) may have different implications in adolescence relative to childhood, such that reduced social pursuit in adolescence may be more impairing than that during childhood (Crone & Dahl, 2012).

A second issue pertains to how stress may be related to familial risk. There have been numerous distinctions made between different forms of stress (Constance Hammen, 2005; Monroe, 2008; Vrshek-Schallhorn et al., 2013). Key to these distinctions are dependent interpersonal stressors, which are events that are elicited by the behavior of an individual. Recently, Daryanani et al. (in press) found that depressed mothers reported that their adolescent offspring experienced greater amounts of dependent life stressors than non-depressed mothers. Thus, there may be compounding influences of family history of depression with experience of adolescent dependent social life stress. In turn, these may jointly influence the development of PVS function.

The plausibility of a model focusing on the interplay between family history and developmental changes has some support. Swartz, Williamson, and Hariri (2015) examined how development and family history each influenced amygdala reactivity during a face matching task (Hariri et al., 2002). The authors reported that youth at high-risk for depression demonstrated significant increases in amygdala reactivity when viewing fearful faces across development, whereas low-risk youth did not demonstrate such increases.

Implications of PVS Function for Prevention of Youth Depression

Thus far, the emphasis of this paper has been on the organizational structure of PVS and relating PVS functioning to risk for depression in youth. There is a need for this work to inform prevention, which is linked with domain structure of PVS functioning; how development influences that presentation; and when to target specific domains of functioning among which risk populations. These echo calls from others when discussing reward processes in youth with a depressive diagnoses (Forbes & Dahl, 2012), but highlight different considerations of what, when, and for whom preventative efforts be focused. Here, however, conjectures are offered to stimulate areas of future attention.

There is often opacity in translating measurement structure to clinical utility. However, the crucial link is for identification of malleable targets of intervention. The domain structure will delineate the constructs that may be targeted in prevention efforts. Further, the domain structure will also inform expectations about how gains in one construct may influence gains (or lack thereof) in another. For example, if the domain structure of the PVS includes a general factor as well as specific factors (i.e., Figure 1c), this would suggest that strategies targeting the general factor would have downward effects on the specific factors. Likewise, strategies targeting a specific factor (e.g., approach motivation) would also influence the general factor, which in turn may influence a different factor (e.g., reward learning). As there is great interdependence between constructs within this model, there is a strong possibility that a single intervention may provide a tremendous impact. In contrast, if the optimal domain structure includes correlated constructs (i.e., Figure 1a), this would suggest that specific interventions may be necessary to address attenuated functions in each. Thus, the degree of specificity of intervention would be greater and the interventions would address only one component process without the likelihood of influencing other correlated constructs. Ultimately, this would suggest that a multiple component intervention would be necessary to improve PVS function and alter the overall trajectory of its development.

Beyond structural differences informing which constructs may be targeted, there may be important considerations about when interventions may best capitalize on naturally occurring development (Dahl, 2004). That is, when constructs are undergoing developmental change, they may be more amenable to being influenced by experience. Thus, if we know when various PVS constructs are typically demonstrate significant developmental change, we may have leverage on timing for when to intervene. Thus, to leverage these periods of developmental change, basic science on the longitudinal development of PVS function needs to be conducted before developmental changes are anticipated to begin and carry through after they are thought to conclude. Thus, potential sensitive periods of PVS development have yet to be fully uncovered.

A further consideration is who should receive these prevention efforts. In their meta-analytic review, Stice et al. (2009) found larger effects with older youth at high-risk for depression (typically based on family risk status or presence of elevated, but not clinically significant symptoms) and involve brief interventions that involved homework assignments among youth from 12-24 years. Thus, targeted prevention approaches appear to be most successful. Stice et al. (2009) did not find that any specific prevention program demonstrated was specifically associated with outcomes. Interestingly, interventions targeting PVS-relevant functioning (i.e., behavioral activation prevention methods) were used least frequently than any others (~33% of trials). Thus, additional work is needed in this area.

Although the available data on prevention in depression focuses on childhood and adolescence, it is important to speculate about prevention much earlier in development. Offspring of depressed parents are at heightened risk for depression (Constance Hammen, Shih, & Brennan, 2004; Klein et al., 2005; Lieb, Isensee, Hofler, Pfister, & Wittchen, 2002) and some evidence suggests that infancy and early childhood are the periods of development most sensitive to parental depression (Bagner, Pettit, Lewinsohn, & Seeley, 2010; Josefsson & Sydsjö, 2007). However, other evidence does not find that timing of maternal depression influences this relationship (Goodman et al., 2011). Regardless of whether there is a critical early period of development, youth early experience with a depressed caregiver is associated with depressive disorders. Thus, prevention strategies that begin very early in life may be particularly promising.

Parent-child interaction therapy (Eyberg, Boggs, & Algina, 1995) and Triple P—Positive Parenting Program (Triple P) (Sanders, 1999) were each developed to be primary interventions for behavior problems in very young children. Both have demonstrated promise in ameliorating these concerns (R. Thomas & Zimmer-Gembeck, 2007). Based on these promising results, these psychotherapeutic approaches, particularly PCIT, have been adapted to target additional youth problems, including depression (Lenze, Pautsch, & Luby, 2011; Luby, Lenze, & Tillman, 2012). PCIT involves negotiation of contingent reward in the form of positive social engagement between and adult and child. Thus, there may be important implications for the development of multiple PVS dimensions over the course of PCIT. Focal investigations of this nature could be particularly fruitful for investigating mechanisms of PVS development.

As the developmental neuroscience literature emphasizes pubertal development as a key point in the development of PVS function, there are two additional intervention strategies that warrant further investigation. Behavioral activation interventions may be important to examine. The goal of this intervention is to engage in one's environment to experience rewards. There is empirical support for its utility with adults with depression (Cuijpers, Van Straten, & Warmerdam, 2007), but adaptations of behavioral activation therapy for adolescents are new (McCauley, Schloredt, Gudmundsen, Martell, & Dimidjian, 2011). In the first clinical trial of behavioral activation in adolescents, McCauley et al.(in press) finds promising support for behavioral activation for adolescent depression, demonstrating treatment effects comparable to those achieved from evidenced based interventions for depression. Future work will need to address whether this intervention approach specifically modulates reward function.

Second, savoring interventions (McMakin, Siegle, & Shirk, 2011) may also be fruitful. This intervention approach emphasizes cognitive processing of the anticipation and experience of rewards. Thus, methods attempt to enhance the length of time that one draws positive affect from the experience. As individuals need to experience positive events to draw on these cognitive processes, behavioral activation is partially integrated into the treatment. However, there are no published studies documenting the utility of this approach with patient populations. Nonetheless, due to the intervention targets these are promising strategies for consider for augmenting PVS function. Attending to intervene on the PVS may help prevent onset of depression. However, more work is necessary to identify the specific constructs that are amenable to behavioral activation and/or savoring interventions.

Overall Summary

The PVS is a complex domain with multiple constructs under the umbrella. Currently, we are in the very early stages of comprehensively understanding the nature of these constructs; how they develop; the specificity of links to depressive disorders; and means to intervene to facilitate PVS development. There are numerous opportunities to further this body of research by connecting hypothesized PVS constructs to constructs germane to developmental science and may connect these distinct literatures. Further, it is appealing to consider how different atypical patterns of OVS development may be related to other forms of psychopathology (e.g., substance use or bipolar disorders). As other commentaries have stated (Forbes, 2009; Forbes & Goodman, 2014), there are many unanswered questions with respect to the role of PVS functioning in depression specifically, and psychopathology more generally. Here, I argue that in order to progress in these areas, there is a great need to examine and understand the structure of the PVS in the context of development; examine known risk factors for depression influence the development of PVS function; and use knowledge about the structure provide valuable leverage for preventing the onset of depression. Finally, these developmental extensions should be considered in other RDoC domains. These advancements will hasten advancing application of the RDoC framework to youth psychopathology.

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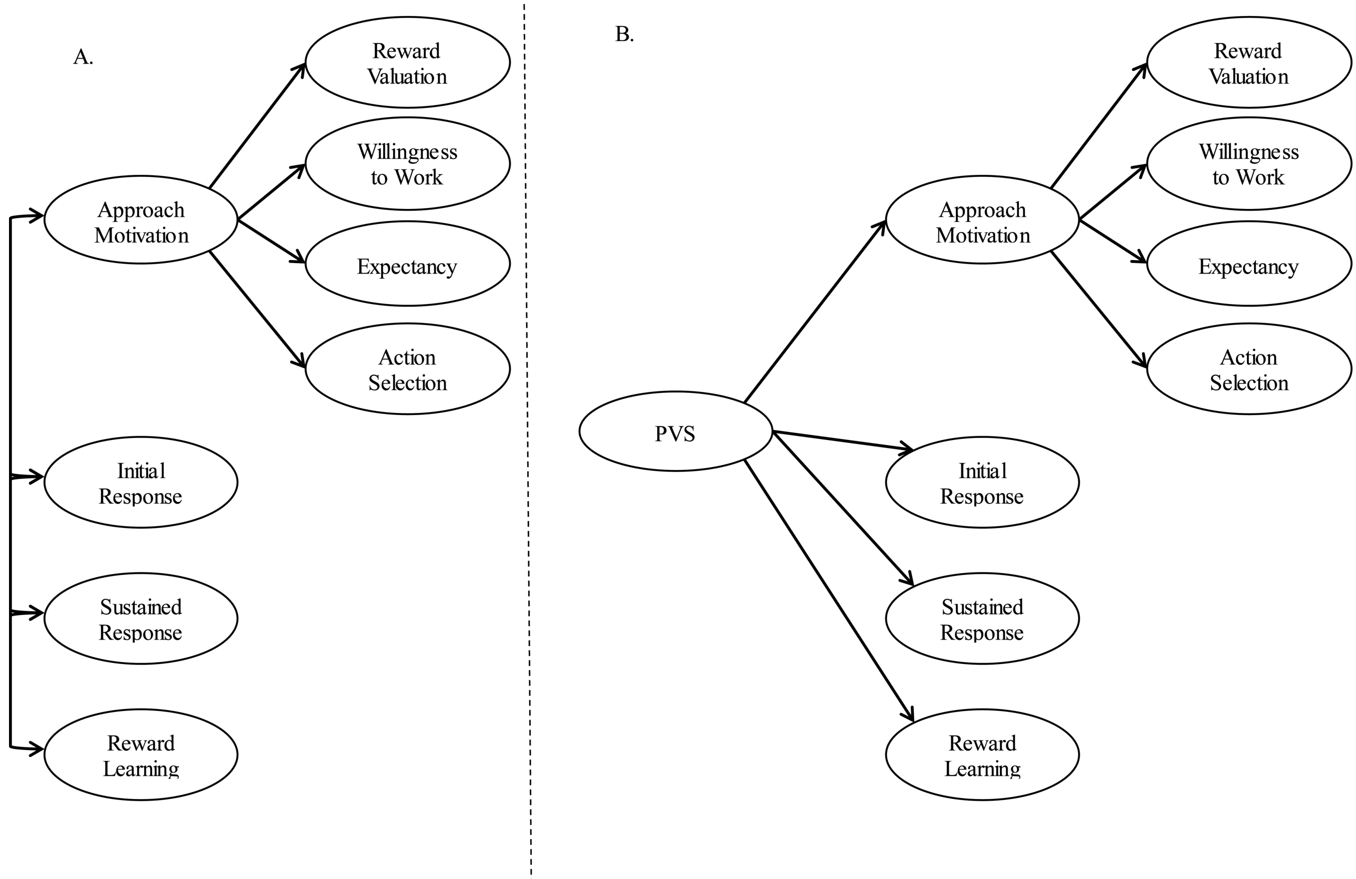
A.
Reward Valuation
Willingness to Work
Approach Motivation
Expectancy
Action Selection
Initial Response
Sustained Response
Reward Learning
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Initial Response
Sustained Response
Reward Learning

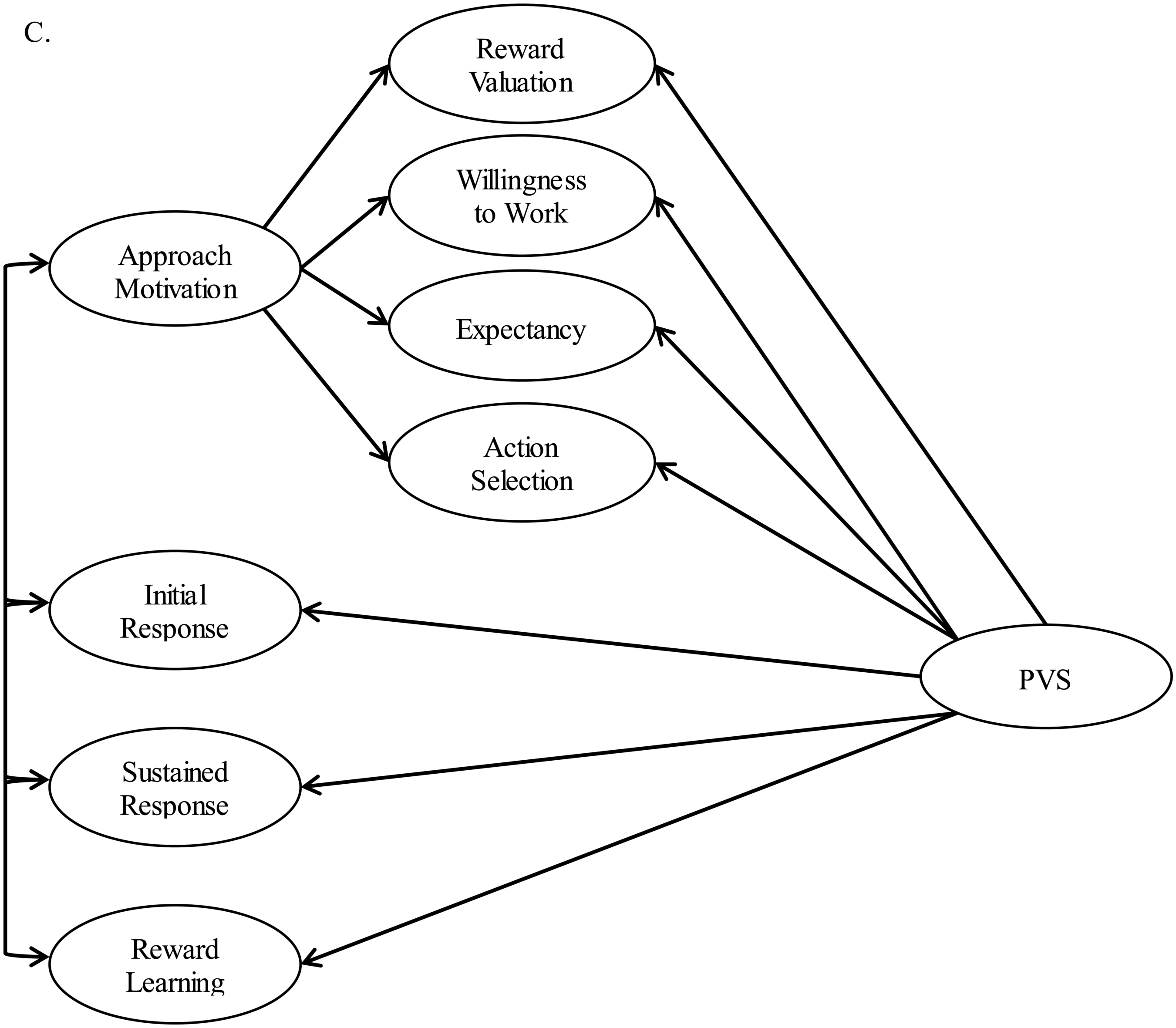

Figure 1.
Schematic Plausible Models for PVS Organization.

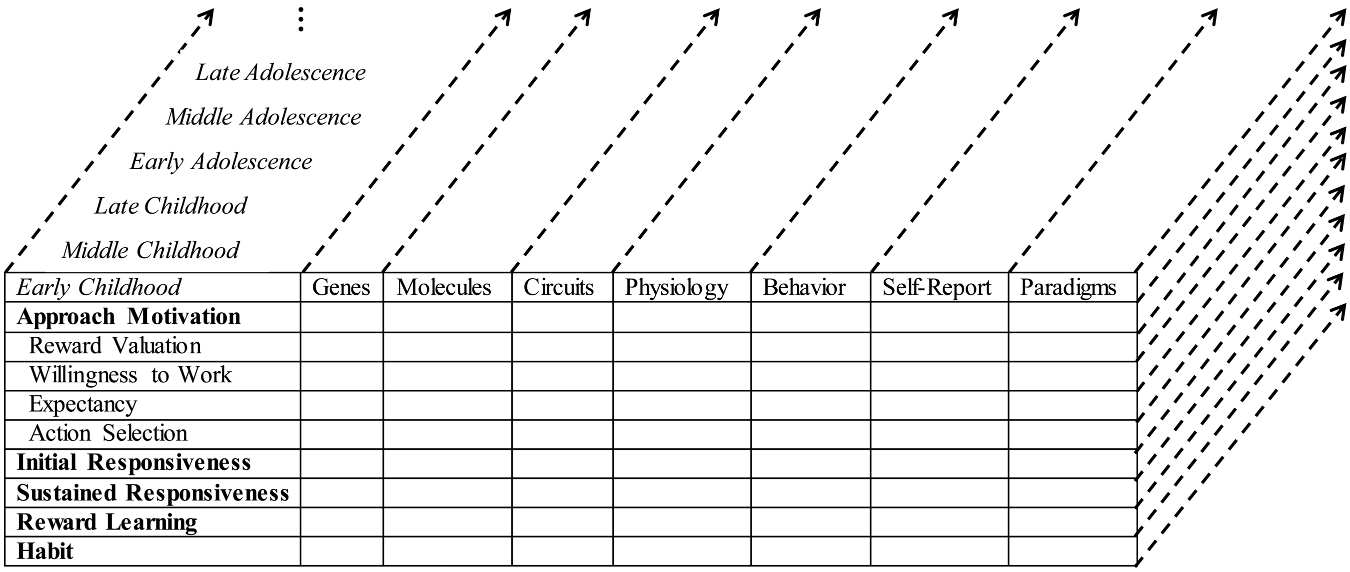

Figure 2.

Schematic developmental extension of PVS.

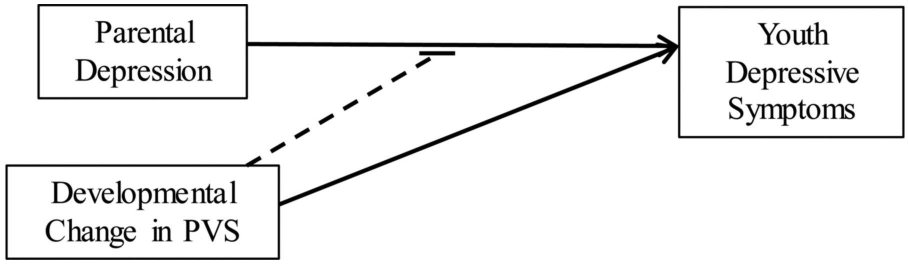

Figure 3a.
Heuristic moderation model of parental depression, developmental change in reward responsivity, and development of youth depressive symptoms.

Solid arrows indicate hypothesized direct influences; Broken arrows indicate potential moderators. Change in PVS includes multiple units of analysis, including self- and parent-reports, behavioral, and neural indices.

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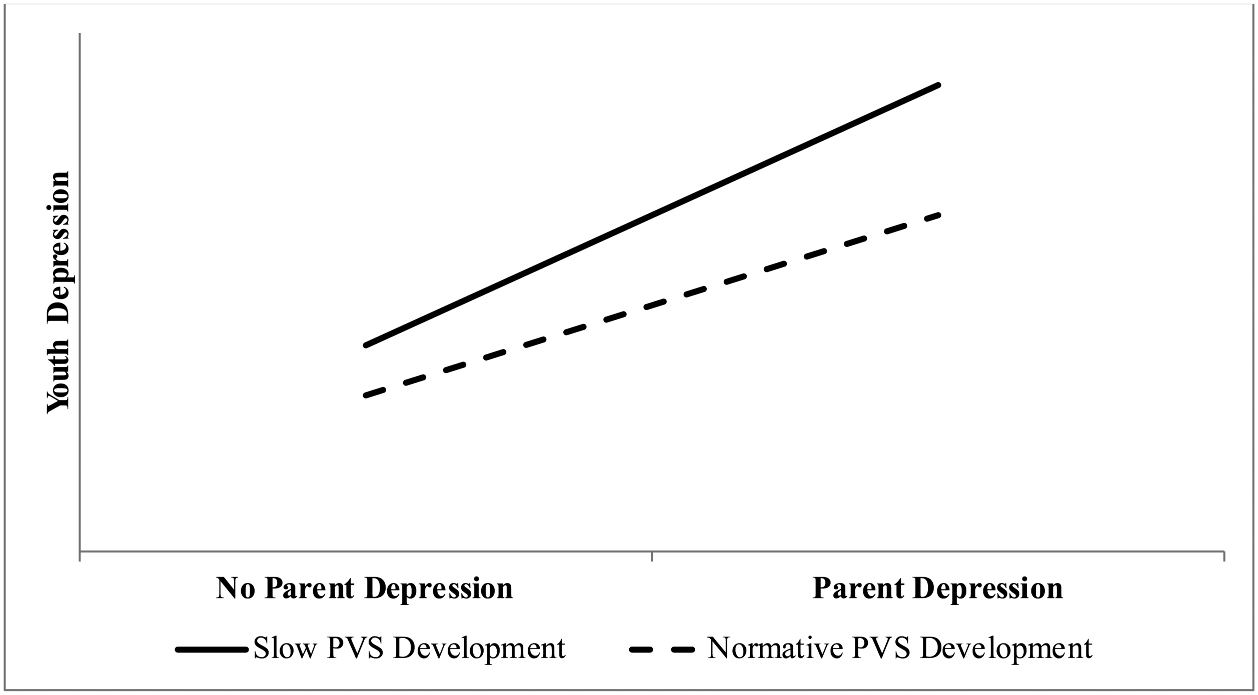

Figure 3b.

Predicted decomposition of moderation of parental depression, developmental change in reward responsivity, and development of youth depressive symptoms.

Table 1

Hypothesized mapping of Rothbart scales on PVS constructs

	IBQ	ECBQ	CBQ	TMCQ	EATQ
Approach Motivation					
Reward Valuation	High Intensity Pleasure	High Intensity Pleasure	High Intensity Pleasure	High Intensity Pleasure	High Intensity Pleasure
Willingness to Work	[Duration of Orienting]	[Attention Focusing]	[Attention Focusing]	[Attention Focusing]	[Attention]
Expectancy of Reward	Approach	Positive Anticipation	Approach		
Initial Responsiveness to Reward	Smiling/Laughter		Smiling/Laughter		
Sustained Responsiveness to Reward					Pleasure Sensitivity

IBQ = Infant Behavior Questionnaire; ECBQ = Early Childhood Behavior Questionnaire; CBQ = Child Behavior Questionnaire; TMCQ = Temperament in Middle Childhood Questionnaire; EATQ = Early Adolescent Temperament Questionnaire. Row headings in **bold** indicate broad constructs. **Preference-based decision making** and **Reward Learning** are not included in the table as no Rothbart scales appear to map to those constructs. Rothbart scales noted in braces are tentative mappings.