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Executive functioning moderates the relationship between motivation and adolescent depressive symptoms

Chrystal Vergara-Lopez, **Hector I. Lopez-Vergara**, and **Craig R. Colder**
University at Buffalo, The State University of New York, Department of Psychology, 242 Park Hall, Buffalo, NY 14260 USA

Abstract

We investigated the association between adolescent depressive symptoms and components of executive functioning (EF), including planning (Tower of London), set-shifting (Wisconsin Card Sorting Task), and inhibition (Stop Signal Task) in a community sample of 12–14 year olds. Further, EF was tested as a moderator of motivation (as operationalized by revised Reinforcement Sensitivity Theory) effects on depressive symptoms. Results suggested that planning ability was associated with depressive symptoms. Furthermore, planning ability moderated the relationship between motivation (fight-flight- freeze system; FFFS) and depressive symptoms, such that among adolescents with poor planning ability the FFFS positively predicted depressive symptoms, but among adolescents with strong planning ability the FFFS negatively predicts depressive symptoms. Neither set-shifting nor inhibition was associated with depressive symptoms. Findings highlight the need to consider multiple components of EF and to integrate motivational and executive dysfunction models to the study of depression.

1. Introduction

Neuroscience models implicate deficits in self-regulatory networks in the etiology of psychopathology, including depression (De Raedt & Koster, 2010; Ernst & Fudge, 2009; Spear, 2010). Carver, Johnson, and Joormann (2008) propose that self-regulatory deficits associated with depression consist of: (1) an affective system that encompasses motivational reactivity, (2) a deliberative system that encompasses executive functioning, and (3) that these two systems operate synergistically to produce depression. That is, motivation and executive functioning do not simply have additive effects, but rather may interact in a nonlinear fashion to influence the development and maintenance of depressive symptoms. In this study, we examine interactive effects between motivational reactivity and executive functioning in the prediction of adolescent depressive symptoms.

Motivation represents constitutionally based individual differences in affective reactivity and sensitivity (Rothbart & Bates, 2006). Research indicates that depression is associated with dysregulated motivational systems that lead to weak reactivity to positive events and strong sensitivity to aversive events (see Zinbarg & Yoon, 2008 for a review). More specifically, Fowles (1994) has posited that depression is the result of two motivational

Corresponding author: Chrystal Vergara-Lopez, cvergara@buffalo.edu, 718-813-8347, 242 Park Hall, Department of Psychology, University at Buffalo, The State University of New York, Buffalo, NY 14260 USA.

systems: the behavioral approach and inhibition systems (BAS, BIS). The BAS is sensitive to appetitive stimuli and governs approach motivation, while the BIS is sensitive to conditioned aversive and novel stimuli, and governs avoidance motivation (Gray, 1982). According to this view depression is characterized by a lack of interest in pleasurable experiences (underactive BAS), and sensitivity to aversive events (overactive BIS). Previous research has shown that depression (operationally defined both categorically as a clinical disorder and continuously as depressive symptoms) is associated with an underactive BAS and overactive BIS (Hundt et al., 2007; Kimbrel et al., 2007; Pinto-Meza et al., 2006).

Fowles' conceptualization of depression was based on the original version of Gray's theory (1982). According to the revised reinforcement sensitivity theory (r-RST, Gray and McNaughton, 2000), the BAS remains unchanged, but the functions of the BIS and a third system, the fight-flight-freeze system (FFFS), are re-conceptualized, and these changes have implications for models of depression. In the r-RST, the BIS is a comparator that assesses and resolves goal conflict and favors "safer" goal pursuits. The FFFS guides responses in the context of immediate/actual threat and is associated with behaviors such as freezing (i.e., behavioral shutdown) and withdrawal. Extending the r-RST to Fowles's view of depression and consideration of the literature cited above would suggest that an underactive BAS (low reactivity to appetitive stimuli and pursuit of pleasurable experiences), and an overactive FFFS (high reactivity to aversive stimuli), but not an overactive BIS, will be associated with depressive symptoms. The relationship between the r-RST motivational systems and adolescent depression has received limited empirical attention.

Executive functioning (EF) represents cognitive processes, including the ability to sustain and shift attention, inhibit pre-potent responses, hold information in working memory, and plan responses (Pennington & Ozonoff, 1996). Studies that examine the EF-depression link have found that depression is associated with several EF deficits including planning, set-shifting and inhibition (e.g., Brooks et al., 2010; see Fossati, Ergis, Alliaire, 2002 for a review). However, most of this research has focused on simple main effects of EF. Yet, emerging evidence from neuroscience (e.g., Ernst & Fudge, 2009; Spear, 2010) suggest that the effect of motivational systems on depression is likely to vary as a function of the individual's capacity for executive processes to modulate and regulate motivational impulses. In other words, motivational risk for depression may be particularly difficult to regulate in the context of limited EF resources, making the combination of a depressogenic motivational style and poor EF an especially toxic correlate of depression. Alternatively, higher capacity for EF is likely to diminish the effects of motivational risk on depressive symptoms, such that motivation will have a weak association (if any) with depressive symptoms, as these individuals may have the capacity to modulate and override motivational risk factors. There is a notable paucity of research examining the interactive effects of motivation and EF on adolescent depressive symptoms, and thus a key feature of neuroscience accounts of depression remain untested. This is an important limitation of the literature. The aim of the current study is to investigate the moderating role of EF in the relationship between motivation and adolescent depressive symptoms.

The current study conceptualizes motivation via the r-RST, and will investigate if EF moderates the effects of the BAS, and FFFS in the prediction of adolescent depressive symptoms. EF includes multiple components that contribute both shared and unique variance to outcome variables (Miyake et al., 2000). Yet few studies of depression have considered the simultaneous influence of multiple components of EF, thus it is unclear which EF deficits are most germane to adolescent depressive symptoms. Our investigation contributes to the literature by examining 3 widely studied components of EF: Planning, set-shifting, and inhibition.

In testing a moderational model, we address several other methodological limitations of prior studies examining the role of EF in adolescent depression, including small sample sizes (n's ranging from 30–39), age heterogeneity (e.g., ages that span 6 –17) (e.g., Brooks, et al., 2010), and reliance on clinical samples. Small sample sizes limit power to detect associations. Wide age ranges are problematic because there is substantial development of EF from childhood to adolescence, with some components of EF continuing to develop until late in adolescence (Spear, 2010). Studies that collapse across childhood and adolescence may obscure these developmental differences. Accordingly, it is important to test the association between EF and adolescent depressive symptoms in a large age homogenous sample.

Reliance on clinical samples is a limitation for several reasons. Only one-fourth to one-half of adolescents with depression receive mental health services (Kessler & Walters, 1998). Thus, clinical samples are not fully representative of adolescent depression, and include the most dysfunctional adolescents; using clinical samples can result in restricted range of scores, resulting in attenuated relationships between constructs of interest. Further, there is taxometric evidence that adolescent depression is best conceptualized as a continuum (Hankin, et al., 2005). Thus, community samples may have some advantage relative to clinical samples because they include a more representative range of symptoms of depression, as well as, of EF and strength of motivational systems.

In sum, this study investigates the influence of r-RST motivational systems and EF in the prediction of adolescent depressive symptoms. We address limitations in the literature including conceptualizing motivational risk according to the r-RST rather than the original theory, considering three facets of EF, testing motivation x EF interactions, and utilizing a large community sample of early adolescents (12–14 years old).

We hypothesized that an underactive BAS and an overactive FFFS would be associated with higher levels of depressive symptoms. The BIS was expected to have no association with depressive symptoms, in accordance with the r-RST. We also hypothesized two-interaction terms with EF, such that an underactive BAS and an overactive FFFS would predict depressive symptoms for those with poor EF. We don't provide EF component specific hypotheses due to limited and inconsistent findings in the literature on multiple components of EF. Anxiety symptoms are associated with depressive symptoms (e.g., Cannon & Weems, 2006), and so we included anxiety symptoms as a statistical control variable so that we could examine the association of motivation and EF with depressive symptoms above and beyond anxiety symptoms.

2. Methods

2.1. Participants

The community sample was recruited via random digit dialing in Erie County, NY as part of a longitudinal study investigating behavior problems and substance use. Eligibility criteria required the child to be 11–12 years old during the first wave of assessment, understand English well enough to complete the assessments, and have no disabilities that would preclude completion of the assessment battery (e.g., mental retardation). The sample at wave-1 included 387 families (1 caregiver; 1 child) and at wave-2 included 373 families (4% attrition rate). Data for this study is from the second wave of data collection, when multiple EF components were assessed. Adolescents' mean age at Wave-2 was 13.13 (*SD*=. 61), 55% of the sample were female, and the median family income was $70,000. The majority of children were non-Hispanic White (82.57%), 9.38% as African American, 4.84% as Native American, 1.07% as Hispanic, and 2.14% were described as "other" (e.g., mixed ethnicity). Most of the adolescents were from two-parent families (75.07%).

2.2. Procedures

At wave-2 participants completed questionnaires and EF computer tasks. After consent/ assent procedures, the caregiver and child were escorted to separate rooms to complete the measures. Of interest to this study, caregivers completed a parent report measure of the adolescents' reinforcement sensitivity and the adolescents completed three computer task measures of EF and a self-report measure of depressive symptoms. Families were compensated $85 dollars for their participation and adolescents earned a prize.

2.3. Measures

The Revised Sensitivity to Punishment and Sensitivity to Reward Questionnaire for Children (SPSRQ-C revised; Colder et al., 2011)—This measure is a caregiver informant questionnaire consisting of 33 items. Caregivers used a 5-point response scale anchored by strongly agree to strongly disagree. Factor analysis supports five scales for this measure (Colder et al., 2011). The fear/shyness scale (α=.87) and the anxiety scale (α=.61) correspond to the FFFS and BIS, respectively. There are also three reward sensitivity subscales of drive (α=.69), social approval (α=.65), and impulsivity/fun seeking (α=.75) corresponding to the BAS. Colder and colleagues have shown these scales to be associated with problem behaviors, other temperament scales, and laboratory assessments of reinforcement sensitivity as predicted by r-RST (Colder et al., 2011; Colder & O'Connor, 2004; Rhodes et al., 2011). Furthermore, in their review of temperament research, Rothbart and Bates (2006) concluded that caregivers provide important and valid information about individual differences.

The Wisconsin Card Sorting Test (WCST; Heaton, et al., 1993)—The computerized version of the WCST was used to assess the ability to shift a problem solving strategy in response to changing contingencies. Participants match a series of response cards to stimulus cards that depict figures that vary in form, color and number without being informed of the correct sorting criteria. The rule for sorting the card randomly changes throughout the course of the experiment and participants must be able to switch matching strategies. The dependent variable is the amount of perseverance on an inaccurate rule set.

The Tower of London-Drexel Version 2nd Ed. (TOL; Culbertson & Zillmer, 2001; Davis & Keller, 1998)—The computerized TOL was used to assess executive planning abilities. Participants rearrange beads to match a model in the minimum number of moves possible. This task consists of 10 test items of increasing difficulty. Participants have a maximum of 120 seconds to complete each item. The TOL is scored by subtracting the minimum number of moves required to solve an item from the participant's observed moved count, and adding the difference scores for all 10 items. Higher scores indicate poor executive planning abilities.

The Stop Signal Task (Logan, Schachar, & Tannock, 1997; SST)—The computerized SST was used to assess the ability to inhibit a dominant response. Participants discriminate between arrows pointing left and right (i.e., pressing a "left" button when an arrow points left and pressing a "right" button when an arrow points right) and involves 1 practice "go" block (32 trials) and 1 practice "stop" block (32) trials. After completion of the practice blocks participants complete 3 experimental blocks with 64 trials each. The SST is scored by calculating the stop signal reaction time (SSRT), which is computed by subtracting the mean stop delay (the delay between the stop and go signal) from the mean reaction time (the average time it took to respond to the go signal). Higher SSRT scores suggest poor inhibitory control.

Youth Self-Report (YSR; Achenbach & Rescorla, 2001)—This is a self-report measure of internalizing and externalizing symptoms with items rated on a three point scale ranging from 0 (not true) to 2 (very true). The measure in its original form does not distinguish depressive and anxiety symptoms. Lengua et al., (2001) developed a scoring approach that map onto DSM-IV categories for depression and anxiety. These scales do not confound the measure of depression and anxiety and demonstrate better sensitivity, predictive power, and discriminant validity than the original internalizing scale. In the current study we used the Lengua et al., (2001) depression scale which includes 12 items (e.g., feels worthless, unhappy, lonely) and the anxiety scale which includes 7 items (e.g., fearful, worrying, nervous). Polychoric correlations were used to estimate the internal consistency of these measures because of the ordinal nature of the response scale; reliabilities were acceptable (depression α=.91; anxiety α=.85). The depression score was calculated by taking the mean of the items and the range of scores was from 0 – 1.5 with a mean score of .20 (SD= .23).

3. Results

Correlations, means, and standard deviations for all variables are shown in Table 1. EF and r-RST variables were mostly unrelated, suggesting that these measures are assessing different processes. The three EF measures did not correlate with each other, providing no support for the notion of EF as a unitary construct. High levels of anxiety symptoms were correlated with high levels of depressive symptoms. Anxiety symptoms were also reliably, but modestly correlated with the BIS. However, anxiety symptoms were not related to the FFFS. BIS and FFFS were moderately correlated. These bivariate associations support the distinction between the BIS and FFFS and provide some discriminant validity for the FFFS and BIS with respect to anxiety symptoms. Also notable was that higher levels of depressive symptoms were correlated with higher levels of BIS.

Gender, age, anxiety symptoms, r-RST, and EF variables were entered into a regression model in a first step, the r-RST x EF variable cross-product terms were entered in a second step. Simple slope tests of significant interaction terms were conditioned on 1 standard deviation above and below the mean of the moderator.

Regression analyses at Step-1 showed that higher levels of anxiety symptoms were associated with higher level of depressive symptoms (β= .63, p<.01). There were no first order effects of gender, age, r-RST variables, the WSCT, or the SSRT on depression symptoms. Greater number of moves on the TOL, which is indicative of poor planning abilities, was associated with higher levels of depression symptoms (β= .11, p<.01). When interaction terms were introduced in Step-2, the FFFS x TOL interaction term reliably predicted depression symptoms (β= .01, p=.05). The FFFS was positively associated with depressive symptoms at high (β=.03, p= .06) levels of the TOL (poor planning ability), and negatively associated at low levels of the TOL (strong planning ability) (β= −.02, p=.06). Both of these simple slopes were marginally significant falling short of conventional levels of significance. The full model accounted for 50.3% variance in depressive symptoms. Consistent with interaction effects in the social sciences (McClelland & Judd, 1993), the FFFS x TOL interaction term accounted for a small percent of unique variance (.6%).

4. Discussion

Neuroscience accounts of depression suggest that motivation and EF may operate interactively, yet few studies have tested such a moderational model. We tested whether multiple facets of EF moderated the association between individual differences in motivation (as conceptualized according to the r-RST) and depressive symptoms. The three facets of EF: planning, set-shifting, and inhibition were independent of each other in our community sample of early adolescents. These results are in line with multi-component views of EF. Consistent with our hypothesis, the association between motivation and depressive symptoms was moderated by EF, but this interaction was limited to the FFFS and planning ability. Specifically, planning ability moderated the relationship between motivation (FFFS) and adolescent depressive symptoms, such that among adolescents with poor planning ability, the FFFS was positively associated with depressive symptoms, but among adolescents with strong planning ability the FFFS was negatively associated with depressive symptoms.

Planning abilities reflect the capacity to keep an end goal in mind, generate possible solutions, identify the best solution, and execute the solution (Berg & Byrd, 2002). These steps represent important aspects of coping as poor planning hampers effective coping (Bell & D'Zurilla, 2009; Nezu et al., 2004), and poor coping has been identified as a robust predictor of depression (e.g., Nezu & Ronan, 1987). Our findings suggest that a strong FFFS may be a risk factor for depression but only in the context of poor EF. According to the r-RST (Gray & McNaughton, 2000) framework, the FFFS is activated by aversive stimuli and is associated with responses such as freezing (i.e., behavioral shutdown), withdrawal, helplessness, fatigue, and emotional reactions. Our findings suggest that poor planning exacerbates the effect of strong emotional reactions to aversive stimuli/stressful events (i.e., strong FFFS), perhaps resulting in insufficient problem solving resources, ineffective navigation of the environment and increased levels of depressive symptoms. This finding offers some support for neuroscience models that suggest that EFs function to modulate behavioral impulses is governed by motivational systems (Ernst & Fudge, 2009), and that when there is a failure to effectively modulate strong motivational drive, depressive symptoms emerge.

Interestingly, our results suggest that high capacity to executive planning may buffer against the effects of strong sensitivity to aversive stimuli (an overactive FFFS). Williams and colleagues (2009) argue that individual differences in EF will alter an individual's response to stress such that poor EF leads to maladaptive coping and stress reactivity, while good EF leads to resilience by facilitating problem solving, modifying behavior in response to the environment, planning and generating coping strategies. Our finding supports the view that good EF can function as a resilience factor.

The finding that planning ability, but not set-shifting or inhibition, was associated with depressive symptoms (either as a first-order effect in interaction with EF) was surprising. Planning ability maybe particularly important in early adolescence and other EF deficits may be more relevant later in development as adolescents enter more complex internal and external environments. Alternatively, it may be that deficits in set-shifting and inhibition develop as a consequence of repeated depressive episodes, and our early adolescent sample may not yet have experienced repeated depressive episodes. It will be important for future research to how and when deficits in set-shifting and inhibition may be relevant to depression.

Why the BAS was unrelated to depressive symptoms is unclear. Although correlations suggested that some aspects of the BAS were associated with depressive symptoms, BAS scales were unrelated to depressive symptoms in our multivariate model. The FFFS has been neglected in human studies of psychopathology and adjustment largely because of a lack of measures tapping into the FFFS and the continued adoption of the original RST as a theoretical framework, which places less emphasis on the FFFS than does the r-RST. To our knowledge, this is the first study to test the association between the FFFS and adolescent depressive symptoms. Several theorists have conceptualized depression as a disorder that increases sensitivity to aversive experiences (e.g., Fowles, 1994). However, many depression researchers continue to use the original RST and posit that sensitivity to aversive experiences is governed by the BIS (e.g., Hundt et al., 2007; Kimbrel et al., 2007). As Corr (2008) explains, the FFFS, not the BIS, governs responses to current aversive events. It seems that the RST account of depression needs to be re-conceptualized to include the role of the FFFS.

The general lack of effects of motivation on depressive symptoms may be attributed to motivation having an indirect effect on depressive symptoms. Individual differences are thought to promote transactions between the individual and the environment to increase vulnerability to depression (Gotlib & Hammen, 2009), and cumulative and interactive effects of aversive negative events may be necessary for motivation to impact depressive symptoms. Davey et al. (2008) posits that adolescent depression is related to trait-like variables only after exposure to numerous failed attempts of attaining rewards from the environment. Our early adolescent sample may not yet have experienced sufficient accumulation of aversive events for motivation to strongly impact the emergence of depressive symptoms.

Although this study makes an important contribution regarding the role of EF and motivation on adolescent depressive symptoms, it is important to note some limitations. First, we used a dimensional view of depression instead of DSM-IV diagnostic criteria. While there is evidence that adolescent depression lies on a continuum rather than a category (Hankin et al., 2005), the results might not generalize to clinical samples. Secondly, these findings may not generalize to other age sample (e.g., late adolescence, young adulthood). Third, this was a cross-sectional design, which leaves open the question of direction of effects. Lastly, some of our measures had marginally acceptable reliabilities, which may have attenuated some of the observed associations.

In conclusion, our findings suggest that it is important to assess multiple aspects of EF, as assessing only one component will provide limited insight into the etiology of depression. Furthermore, two prominent models have been posited to account for adolescent depressive symptoms, which include motivational systems and EF deficits. From a motivational r-RST framework, low approach motivation and high sensitivity to aversive events put individuals at risk for depression. EFs reflect an ability to successfully regulate internal (e.g., thoughts and emotion) and external (e.g., behaviors) responses. Individuals with EF deficits are posited to be at risk for depressive symptoms because they do not possess the ability to self-regulate. Current neuroscience accounts of depression suggest a theoretical integration of these two frameworks, such that motivation and EF may operate interactively to predict higher levels of depressive symptoms (Ernst & Fudge, 2009). The present study provides some support for such a theoretical integration, and highlights the need to move beyond simply pitting motivation and EF variables to consider more complex and theoretically driven moderational models of adolescent depression.

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- Operationalized motivation via revised Reinforcement Sensitivity Theory
- Used a multi-component view of executive functioning
- Administered three different computerized executive functioning tasks
- We used a large community sample of early adolescents
- Planning ability interacted with the FFFS to predict depressive symptoms

Table 1

Correlations and Descriptive Statistics

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	Mean	SD
1. BAS- Drive	1.00												3.15	.70
2. BAS- SA	.27***	1.00											3.18	.61
3. BAS- I/FS	.36***	.18***	1.00										2.52	.64
4. BIS- Anxiety	−.04	.31***	.24***	1.00									2.91	.66
5. FFFS-Fear/Shy	−.31***	.05	.09	.48***	1.00								2.63	.76
6. TOL	.01	.02	.02	−.01	.03	1.00							90.06	17.76
7. WCST	.06	.02	.15**	.04	.02	.09	1.00						11.17	5.60
8. SSRT	−.06	.04	.06	.05	−.04	.04	.02	1.00					157.70	51.87
9. Depression	.08	.05	.19***	.17***	.04	.15**	−.00	.01	1.00				.20	.23
10. Anxiety	.01	.01	.06	.20***	.06	.06	−.06	−.09	.66***	1.00			.31	.30
11. Gender[a]	−.10	.06	−.25***	.09	.11*	.03	−.08	−.08	−.14**	−.04	1.00		1.55	.50
12. Age	−.03	−.10*	.00	−.10	.10	.05	−.07	−.11*	.02	.02	.04	1.00	13.13	.60

Note:

* p<.05,

** p<.01,

*** p<.001,

[a] dichotomous variable coded

1=male, 2=female, BAS=Behavioral activation system, BIS= Behavioral inhibition system, FFFS= Fight Flight and Freeze system, TOL= Tower of London, WCST= Wisconsin Card Sorting Test, SSRT= Stop Signal Reaction Time.